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THE STARK EFFECT IN HELIUM AND NEON

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Stark[1] and Koch[2] have studied the effect of an electric field on the spectral lines of helium by a method which was designed by Stark. Brunetti[3] and Evans and Croxson[4] nave studied the effect in the same substance by a method devised by Lo Surdo.[5] The results obtained by the two methods agree in the main, but hitherto the method of Stark has proved capable of greater refinement than that of Lo Surdo.

In the present investigation a method has been employed which is essentially a modification of Lo Surdo's but avoids the greatest disadvantages of that method. Lo Surdo's discharge tube is about 3 mm. in diameter and has a cylindrical cathode nearly filling it. The positive rays in the space before the cathode are in a strong field and are suitable for the study of the effect. The disadvantages of the method are, first, that the walls of the tube are quickly covered with a metallic film due to sputtering and, second, the tube breaks easily on account of the heating. In the present apparatus these difficulties are overcome by having within the discharge tube proper an inner tube made of aluminum through which the discharge takes place, and which has a slit through which the light passes. Opposite this slit there is a side tube having a window at its end. The aluminum is not seriously affected by the heat and the trouble from sputtering is eliminated.

The optical apparatus consists of a six prism spectrograph and a double image prism so arranged that photographs of the parallel and perpendicular components of the lines can be obtained simultaneously.

The source of current is a 13,200 volt transformer, the current from which is rectified by two kenotrons and a suitable arrangement of condensers and inductances.

The following is a brief summary of the results obtained in helium and neon:

1. The equation connecting the displacement of a component and the electric field is of the form

$$\delta\lambda = a + bE$$

where a differs from 0 for many components.

2. When $a = 0$, b is positive. Only two exceptions have been found to this rule, viz., He 4686 and He 3965.

3. There are simple numerical relations connecting the values of a for the different components of a given line. Such numerical relations exist to a less degree between the values of b.

4. The effect in the line He 4686 agrees qualitatively with that predicted by Evans and Croxson on Epstein's theory. The numerical

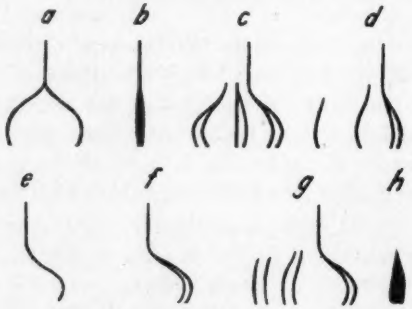

FIG. 1.

value of the ratio of the distance between the outer components of H_γ to that of He 4686, however, was found to be $\frac{24}{3^2 - 2^2}$ instead of $\frac{24}{4^2 - 3^2}$ as predicted by them.

5. Two new lines of the same type as those discovered by Koch were observed in helium. In neon, 34 such lines were observed.

6. In the accompanying figure are shown some illustrations of the lines as they occur on the photographic plate. In these drawings the wave-length increases from left to right. The upper part of the illustrations shows the line as it appears when the field is zero, the lower part shows the effect of the field.

In the modified discharge tube used, the maximum value of the field occurs some distance above the cathode, instead of in its immediate vicinity. This causes the displaced lines to have the form shown instead of the simple Y shape given by Lo Surdo's tube.

The pair of symmetrical components illustrated at (*a*) is typical of the Balmer series of hydrogen. The separation of such components has been taken as a measure of the field, the constant obtained by Stark being used in each case to calculate the field intensity. The form illustrated in (*b*) is typical of lines which show no appreciable Stark effect. While it is distinctly broadened in its lower portion, there is no doubt that the greater part of that broadening is due to increased intensity in the stronger field. The illustration (*c*) represents those components of He 4388 whose electric vector is perpendicular to the field. It shows, in order from left to right, two components having $a<0$ and $b<0$, one component having $a<0$ and $b=0$, one having $a<0$ and $b>0$, and finally two having $a=0$ and $b>0$. The line sketched at (*d*) is He 4922. The type (*e*) is very common in neon as is also type (*f*). A few lines in neon are of the general type illustrated at (*g*). At (*h*) is shown the appearance of a typical new line. It is very broad and intense in the field but does not exist where the field is zero, or at least is so faint that it produces no effect on the photographic plate.

A detailed statement of the results together with a full description of the apparatus and method will be published shortly.

[1] Stark, J., *Elektrische Spektralanalyse chemischer Atome*, Hirzel, Leipzig, 1914; *Ann. Physik, Leipzig*, **48**, 1915, (193).

[2] Koch, J., *Ann. Physik, Leipzig*, **48**, 1915, (98), Cf. J. Stark, *Elektrische Spektralanalyse chemischer Atome*, 73.

[3] Brunetti, R., *Nuovo Cimento, Pisa*, **10**, 1915, (34).

[4] Evans, E. J., and Croxson, C., *Phil. Mag., London*, **32**, 1916, (327).

[5] Lo Surdo, A., *Roma Atti Acc. Nuovi Lincei*, **22**, 1913, (664); **23**, 1914, (82); *Physik. Zs., Leipzig*, **15**, 1914, (122).

NEW ANALYSES OF ECHINODERMS

By F. W. Clarke and R. M. Kamm

UNITED STATES GEOLOGICAL SURVEY, WASHINGTON[1]

Communicated April 18, 1917

In a recent publication of the United States Geological Survey[2] Clarke and Wheeler have reported 250 analyses of the shells and skeletons of marine invertebrates; analyses which were made in order to determine what each class of organisms contributes to the formation of marine limestones. In that investigation the echinoderms and alcyonarians were peculiarly interesting, not only because they were notably magnesian, but also because the proportion of magnesia in them was found to be related to temperature. The warm water forms were all relatively rich in magnesium carbonate, while the cold water forms were much

poorer. In specimens from high latitudes or from very deep water the proportion of magnesium carbonate ranged from 7 to 10%, while those from tropical waters contained from 11 to over 14%. Intermediate conditions of environment gave intermediate values.

This strange relation between composition and temperature naturally suggested to us the desirability of comparing a series of echinoderms from one definite locality; and an opportunity to do so fortunately presented itself. An expedition sent by the Carnegie Institution of Washington, to the island of Tobago in the British West Indies, made a large collection of just such material as we needed; and Dr. Hubert Lyman Clark, who had charge of the echinoderms, kindly furnished us with specimens. All of them were collected at Pigeon Point, in shallow water along shore, and at a temperature of about 28°C. That is, all the specimens came from exactly the same environment, and were, therefore, for our purpose, strictly comparable. The list of them is as follows:

1. *Mellita sexiesperforatus*, Leske. A sea urchin. Adult.
2. *Echinometra lucunter*, Linné. A sea urchin. Half grown.
3. *Tropiometra carinata*, Lamarck. A crinoid. Adult.
4. *Asterina minuta*, Gray. A starfish. Large adult. Weight 0.1009 gramme.
5. *Linckia guildingii*, Gray. A starfish. Young.
6. *Ophiocoma pumila*, Lutken. A brittle star. Adult.
7. *Ophiomyxa flaccida*, Say. A brittle star. Half grown.
8. *Ophiomyxa flaccida*. Adult.

The analyses, reduced to uniformity by rejection of organic matter and water, and recalculation to 100%, are as follows and represent inorganic skeletal matter only.

	1	2	3	4	5	6	7	8
SiO_2	0.15	0.13	0.54	0.70	0.24	0.47	0.66	0.16
$(Al,Fe)_2O_3$	0.39	0.37	0.51		0.26		0.85	0.70
$MgCO_3$	11.91	11.56	13.74	12.53	14.31	12.97	14.95	14.56
$CaCO_3$	85.02	83.87	83.13	86.77	83.42	84.44	79.37	81.02
$Ca_3P_2O_8$	trace	1.85	0.64	trace	trace	0.14	trace	trace
$CaSO_4$	2.53	2.22	1.44	?	1.77	1.98	4.17	3.56
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

In these analyses the silica and the sesquioxides are doubtless impurities, due to adherent sand or mud from which the specimens could not be wholly freed. Analysis 4, of *Asterina*, is incomplete; for the amount of material, only 0.1009 gram, was insufficient for thorough work.

In such a small specimen the unavoidable errors of manipulation become serious, for the reason that they are magnified in the calculations. In this instance even so small an error in weighing as 0.1 mgm. would amount to 0.3 of 1% in the final statement. The material for analysis 6 was also hardly adequate. These two analyses, however, are not worthless, for they show the high percentage of magnesium carbonate which characterizes the organisms from tropical waters; and so too do the others.

The two analyses of sea urchins show less magnesium carbonate than was found in the other echinoderms, and so help to confirm our suspicion that as a group these animals are poorer in magnesia than either the crinoids, the starfishes, or the brittle stars. In the previously published analyses of crinoid skeletons, the highest proportion of magnesium carbonate found was 13.37%, in a specimen from the Aru Islands. The one from Tobago is notably richer. As for the starfishes and brittle stars the maximum figure previously found for magnesium carbonate was 14.08% in a specimen from Culebra; a quantity which is exceeded by three analyses in our new series.

The relation between magnesium carbonate and temperature is strikingly illustrated by four new analyses of starfishes, which we append here for comparison with the Tobago series. They are as follows:

1. *Pontaster tenuispinus*, Verrill. *Albatross* Station No. 2095, between Cape Hatteras and Nantucket. Latitude, 39°.29′.00″ N. Longitude 70°.58′.40″ W. Depth of water, 2456 meters. At that depth the temperature must have been low; not far from 0°C.

2. *Plutonaster agassizii*, Verrill. Collected off Marthas Vineyard, Massachusetts. Depth of water, 584 meters. Bottom temperature 6.6°C.

3. *Odontaster hispidus* Verrill. Collected off Marthas Vineyard. Depth, 245 meters. Bottom temperature 11.1°C.

4. *Astropecten articulatus* Say. West Coast of Florida.

	1	2	3	4
SiO_2	0.31	0.35	0.62	0.24
$(Al,Fe)_2O_3$	0.45	0.18	0.12	0.23
$MgCO_3$	8.86	9.09	10.58	13.02
$CaCO_3$	89.34	89.18	87.16	85.08
$CaSO_4$	0.89	1.20	1.44	1.43
$Ca_3P_2O_8$	0.15		0.08	trace
	100.00	100.00	100.00	100.00

For these starfishes we are indebted to the United States National Museum. They form part of a much larger series carefully selected for us by Mr. Austin H. Clark. The other specimens of the series are yet to be analyzed. These four, however, fall into place with the Tobago echinoderms and with those previously published. The progressive enrichment in magnesia, following increase of temperature, is unmistakable.

[1] This paper is here published by permission of the Director of the United States Geological Survey.

[2] Clarke and Wheeler, *Washington, U. S. Geol. Surv., Profess. Paper*, No. 102, 1917.

ON UTILIZING THE FACTS OF JUVENILE PROMISE AND FAMILY HISTORY IN AWARDING NAVAL COMMISSIONS TO UNTRIED MEN

By C. B. Davenport

STATION FOR EXPERIMENTAL EVOLUTION, CARNEGIE INSTITUTION OF WASHINGTON

Read before the Academy, April 17, 1917

We are about to organize an army of 1,000,000 men and to add greatly to our navy. Within the next few months, over 20,000 commissions will be given, largely to men who have never seen service. It is of primary importance to the conduct of this war that they should be properly selected. In our civil war incompetence of officers was responsible for thousands of unnecessary deaths.

In the past, appointments have been made largely as political favors, a very bad method of selecting. As Mahan says: "In the stringent and awful emergencies of war, too much is at stake for easy tolerance." In this paper I suggest a new method of selection in its particular application to untried naval officers. This method is, in brief, the utilization, among other data, of the facts of juvenile promise and family history.

The basis of this paper is the study of the biographies of 30 naval officers, and genealogies and supplementary data relating to their families. It appears at once that naval officers are of different types—there are naval fighters (like Nelson, Farragut, Porter and Cushing), naval explorers (like Sir John Franklin, McClintock, and our own Wilkes), naval inventors (like Dahlgren), naval diplomats (like Hornby) and so on. Of the 30 officers 14 are clearly *fighters*, and these are utilized in this study.

The essential traits of successful fighting naval officers are (*1*) *Love of the sea*—perhaps an elementary instinct, but not yet fully studied: (*2*) *nomadism*, whose inheritance is known to be sex linked; (*3*) *hyperkinesis*, which is inherited as a dominant trait: i.e., does not skip a

Perry-Rodgers

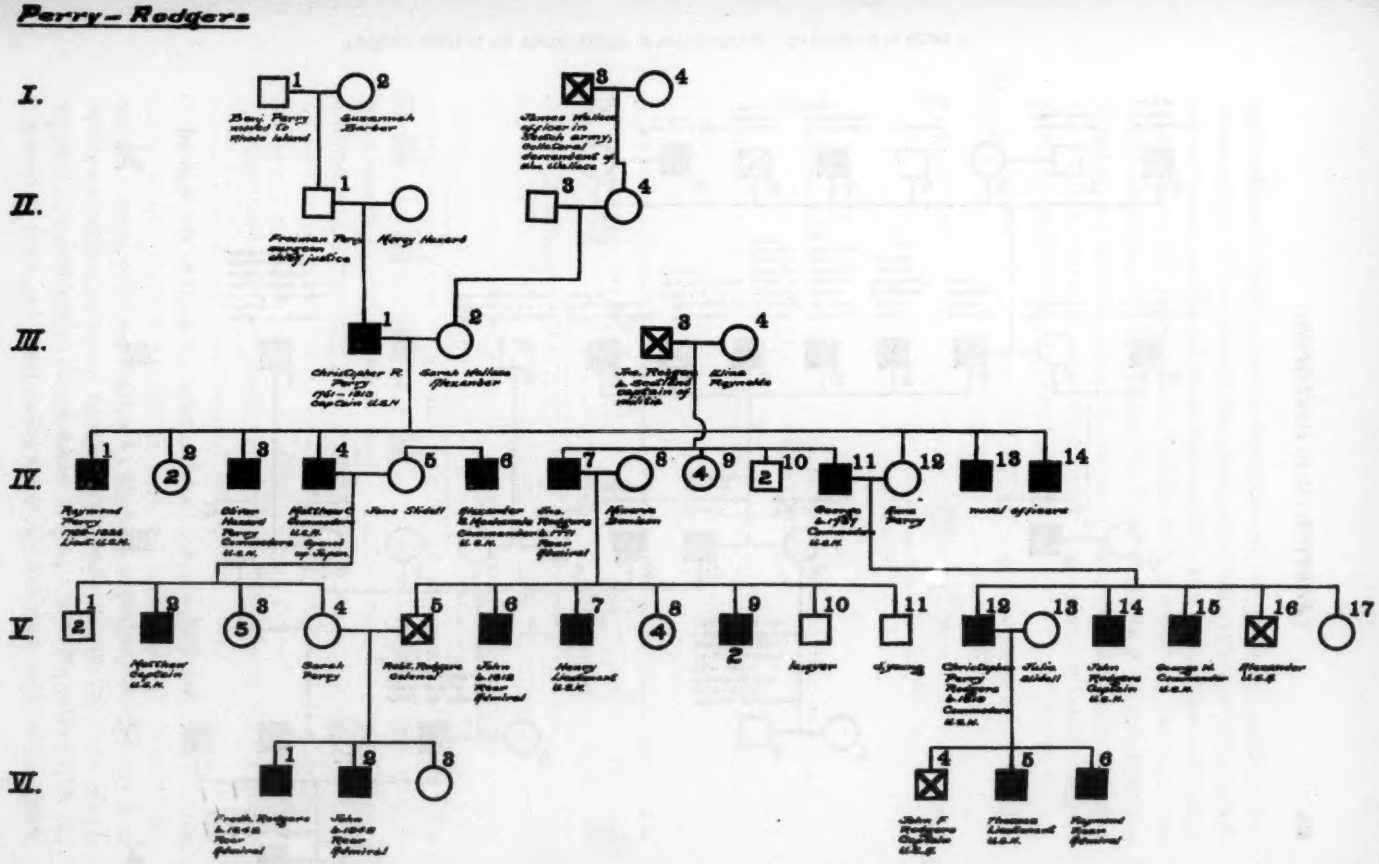

FIG. 1

Pedigree chart of The Perry-Rodgers complex of naval officers. Black symbols indicate men who were either naval officers or captains in the merchant marine. An × in the symbol means a military man. Generations numbered at the left hand margin.

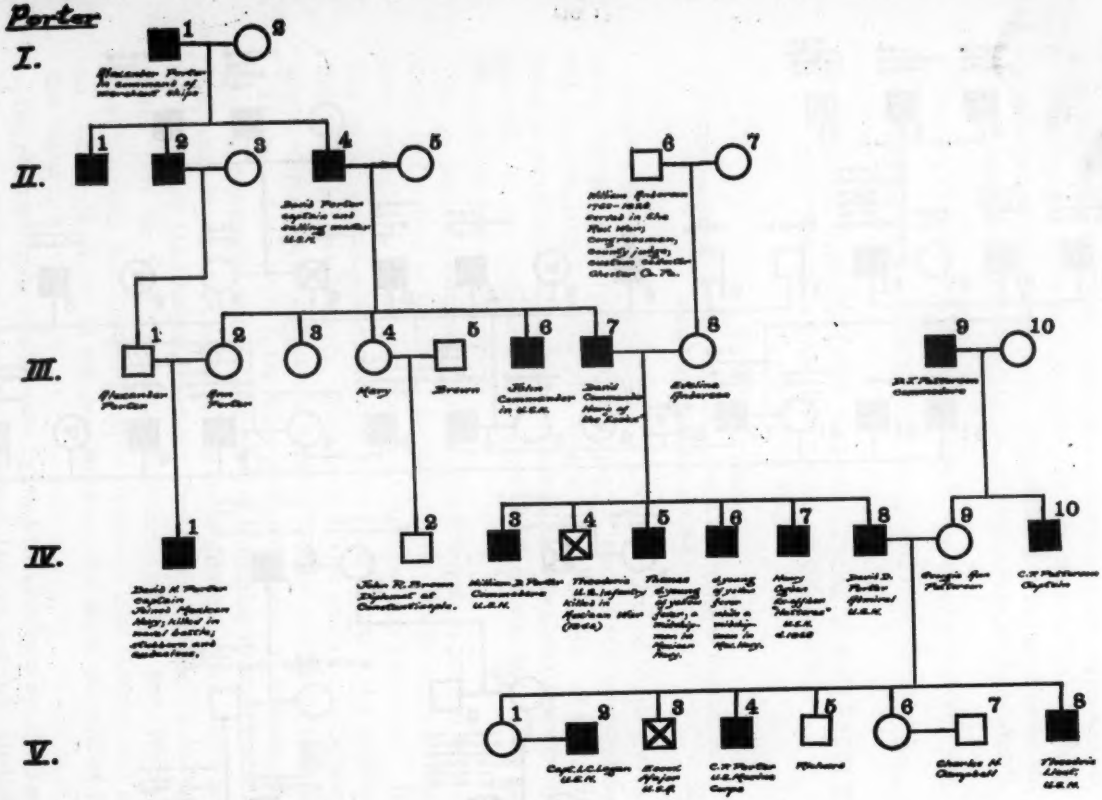

FIG. 2

Pedigree chart of the Porter family of naval officers. Symbols as in figure 1.

generation—it is indicated by energetic activity, push and marked emotional output; (*4*) *absence of fear*, such as permitted Perkins at 6 years to drive, tied in a sleigh, 10 miles and back to town to meet an emergency; or Maffitt at 10 years to travel alone with a ticket on his coat from North Carolina to White Plains, N. Y., in the days of stage coaches; or Winslow, at 10 years, to set to sea in a skiff, with a young cedar tree for a sail, from which he was rescued by an incoming vessel. Important also is (*5*) *ability to command men.*

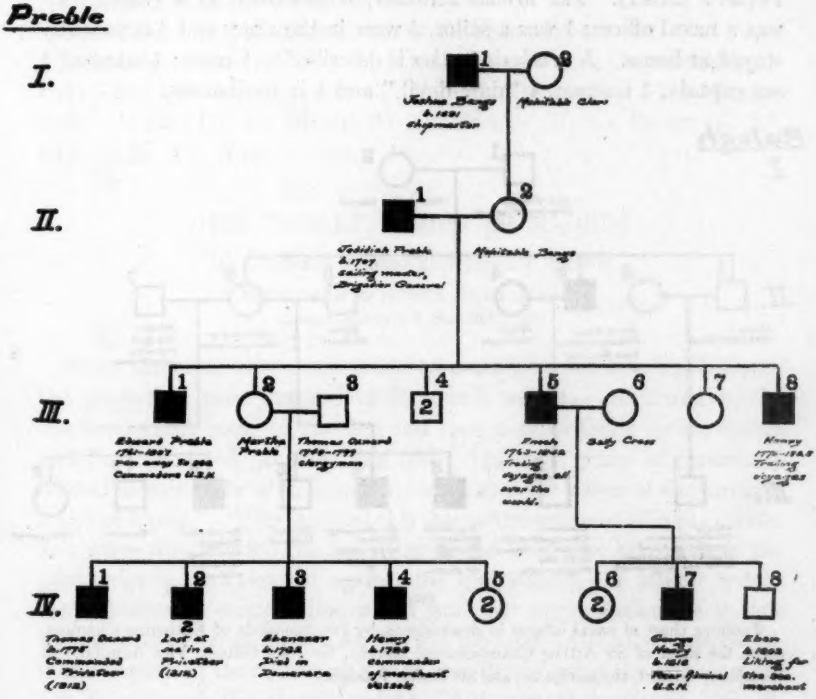

FIG. 3

Pedigree chart of the Preble family. Commodore Edward Preble, U. S. N., is at Generation III, No. 1.

An analysis of these 14 cases of naval fighters shows that all of those about whose youth data could be obtained (11) were adventurous, nomadic, fearless or "quarrelsome." Such then are the juvenile reactions of future successful naval fighters. In temperament 10 were hyperkinetics, 2 hypokinetic, 1 mixed and 1 calm. The hyperkinetic is the commonest reaction of successful naval fighters; but some of the great-

est naval men, like Nelson, have had the somber spirits and the thoroughness of the hypokinetic.

As to family history, there is a record of the *brothers* in 8 cases. In 5, one or more brothers were active in the army or navy, 1 had a nomadic brother; 2 had brothers not especially noteworthy. The *Father*, in 3 cases out of the 14 was a legal man, in 2 cases agricultural, in 2 medical; 1 each was a merchant, inventor, evangelist, 2 were temporarily in the army, 1 was a purser in the navy and 1 was a naval officer (Admiral Porter's father). *The Mother's Father*, is described in 8 cases. One was a naval officer; 1 was a sailor, 3 were in the army and 3 apparently stayed at home. A *Mother's brother* is described in 5 cases: 1 admiral, 1 sea captain, 1 seaman, 1 "dare-devil," and 1 in parliament.

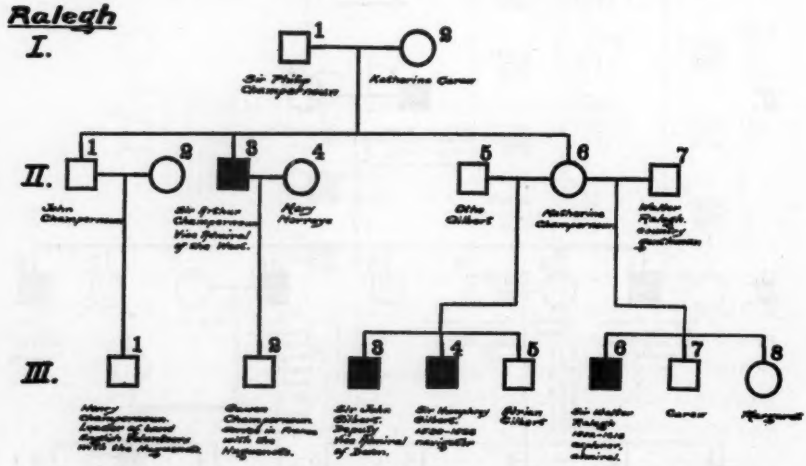

FIG. 4

Pedigree chart of naval officers in descendants, by two husbands, of Katherine Champernoun, the sister of Sir Arthur Champernoun; namely, Sir John Gilbert, Vice Admiral; Sir Humphrey Gilbert, the navigator; and Sir Walter Raleigh.

The conclusion from this study is first; the future fighting naval officer has, in childhood, a history of adventuresomeness and fearlessness. His *mother's* close male relatives (father, or brother, usually) show love of the sea, of travel and of adventure. Some of them are apt to be successful fighters. The hyperkinetic tendency shows in either father or mother. If the father is a naval man and the mother of naval or nomadic stock the chances of a combination for success of the son as a naval fighter are increased. The nomadic and adventurous traits of the great naval fighters are usually carried in the female fertilized eggs

only. Therefore the sons of the daughters, or sisters, of successful naval fighters are more apt to be successful naval men than are the sons or the sons' sons of fighters, unless (as often happens) these fighting fathers marry daughters or sisters of naval men.

Hyperkinesis in either parent gives a favorable prognosis for naval success in the son: but some of the very best naval fighters have been hypokinetics and, under modern conditions of naval warfare, this type is less handicapped than formerly.

Four typical family pedigrees are annexed.

List of the 14 naval officers utilized in this study:—

Bainbridge (U. S.), Barney (U. S.), Cushing (U. S.), Cochrane (Eng.), Paul-Jones (U. S.), Lawrence (U. S.), MacDonough (U. S.), Keppel (Eng.), Maffitt (U. S.), Morris (U. S.), Perkins (U. S.), Porter (U. S.), Battnall (U. S.), Wolsely (Eng.).

THE TRIPLET SERIES OF RADIUM

By Gladys A. Anslow and Janet T. Howell

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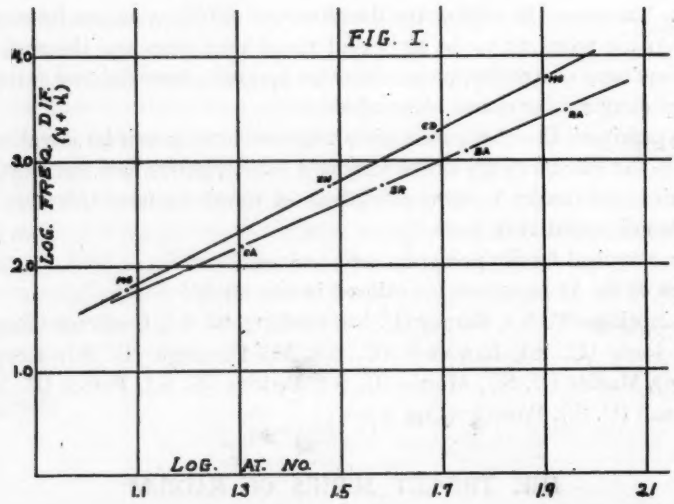
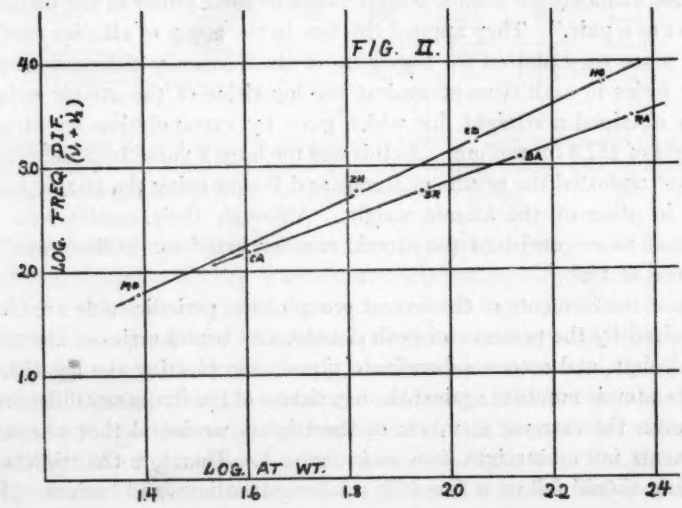
Communicated by G. E. Hale, May 2, 1917

Many attempts have been made to establish a relationship between the spectra of elements and their atomic weights. Referring to the doublets which occur in the first and second subordinate series, Runge and Precht[1] stated the following law. "In each group of chemically related elements the atomic weight varies as some power of the distance apart of a pair." They applied this law to the group of alkaline earths, and when they plotted the logarithm of the frequency difference of the pair series in each element against the logarithm of the atomic weight they obtained a straight line which gave by extrapolation an atomic weight of 257.8 for radium. As this was too large a value Ives and Stuhlmann[2] replotted the results of Runge and Precht using the atomic number in place of the atomic weight. Although their results were in general more consistent the atomic number found for radium was 96 instead of 88.

Now the elements of the second group of the periodic table are characterized by the presence of both doublet and triplet series of the principal, first, and second subordinate types. On plotting the logarithms of the atomic numbers against the logarithms of the frequency differences between the extreme members of the triplets we found that alternate elements fall on straight lines as in figure 1. Therefore the triplets of radium should fall on a line with calcium, strontium, and barium. The



line through these three elements showed that the frequency difference of radium triplets should be approximately 3060. An examination of the known radium lines, measured by Runge and Precht,[3] showd a number of triplets with the average frequency differences, $\nu_1 = 2016.64$; $\nu_2 = 1036.15$; and $\nu_1 + \nu_2 = 3052.79$. Two triplets showed well marked satellites and seemed to belong definitely to the first subordinate series. Although a study of the magnetic resolution of these lines will be neces-



sary to establish the triplets, there seems little reason to doubt that the frequency difference 3053 is characteristic of the radium spectrum.

In figure 2 the logarithms of the frequency differences are plotted against the logarithms of the atomic weights. The general result is the same, but less accurate than in figure 1. The points plotted for radium in figures 1 and 2 are the points found with the actual values for the atomic number and the atomic weight. They fall almost exactly on the lines through calcium, strontium, and barium, in the one case above the line, in the other case below. Extrapolating from the curve we find values of 87 for the atomic number and of 231.7 for the atomic weight, which are remarkably close to the true values, 88 and 226.

The triplets as identified so far are given in table 1. H indicates principal series; I N first subordinate; and II N second subordinate.

TABLE 1

	λ IN A. U.	INT.	$10^8/\lambda$	FREQUENCY DIFFERENCE		λ IN A. U.	INT.	$10^8/\lambda$	FREQUENCY DIFFERENCE
H III 1	6200.6	10	16127.47		I N II 3	5081.2	6	19680.39	2015.07
				1043.15				129.04	
H II 1	5823.9	5	17170.62		I N II 3	5048.1	1	19809.43	2017.74
				2038.13				93.05	
H I 1	5205.96	6	19208.75		I N II 3	5024.5	1	19902.48	2017.77
					I N III 3	4826.12	20	20720.58	1040.19
II N I 3	5958.4	10	16783.03					99.31	
				2015.06	I N III 3	(4803.1)	2	20819.89	1010.46
II N II 3	6319.69	6	18798.09						
				1037.2	I N I 4	4882.3	2	20482.15	
II N III 3	5041.52	6	19835.29					95.35	
					I N I 4	4859.7	1	20577.40	
II N I 4	4997.4	1	20010.41					94.05	
II N II 4				3060.20	I N I 4	4837.59	2	20671.45	
II N III 4	4334.5	5	23070.71						
					I N II 4	4444.4	2	22500.22	2018.07
I N I 3	5660.81	10	17665.32					93.54	
			126.37		I N II 4	4426.0	4	22593.76	2016.36
I N I 3	5620.6	3	17791.69						
			92.92		I N III 4	4245.4	2	23554.91	1054.69
I N 1 3	5591.4	1	17884.61						

In addition to the series triplets in table 1 there are three pairs with a frequency difference of 1035.34 and one of 2017.57 as shown in table 2. There is one weak triplet at λλ 6487.4, 5729.2, and 5409.16 with $\nu_1 + \nu_2 = 3071.16$, which does not fit into any series. A stronger pair at λλ 4903.2 and 4265.1 with a frequency difference of 3051.27 may possibly be a part of the I N 4 group.

TABLE 2

	λ IN A. U.	INT.	$\frac{10^8}{\lambda}$	FREQUENCY DIFFERENCE		λ IN A. U.	INT.	$\frac{10^8}{\lambda}$	FREQUENCY DIFFERENCE
	6167.4	8	16214.29			4366.5	4	22901.64	
				1038.41					1033.25
	5796.2	5	17252.70			4178.0	6	23934.89	
	5811.7	3	17206.67			5907.4	2	16927.92	
				1034.35					2017.57
	5482.15	6	18241.02			5278.3	1	18945.49	

A preliminary attempt at a Rydberg formula gives the following results for the first line of the three classes of triplets:

$$\text{Principal series,} \quad n = 44349.0 - \frac{109675}{(m + 1.0855)^2}$$

$$\text{First subordinate series,} \quad n = 25236.8 - \frac{109675}{(m + .8062)^2}$$

$$\text{Second subordinate series,} \quad n = 25153.0 - \frac{109675}{(m + .6196)^2}$$

It is very probable that further investigation will modify these formulae, but the existence of the triplets seems well established, and the fact that alternate elements in the chemical table show a spectroscopic relation is suggestive for further work along this line.

[1] Runge, C., and Precht, J., *Phil. Mag., London*, **5**, 1903, (476).
[2] Ives, H. E., and Stuhlmann, O., *Physic. Rev., Ithaca, N. Y.*, (Ser. 2), **5**, 1915, (368).
[3] Kayser, H., *Handbuch der Spectroscopie*, vol. 6, p. 325.

THE MEASUREMENT OF SMALL ANGLES BY DISPLACEMENT INTERFEROMETRY

By Carl Barus

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Communicated April 21, 1917

Parallel rays retracing their path.—The following method was devised with a view to the micrometric measurement of angles. It is to be used below in connection with an electrometer for reading microvolts. An interference method of a different kind for measuring small angles was developed some time since and used at length in connection with the deviation of the horizontal pendulum.[2] Again the electrometer was treated in different ways[3] by the aid of the displacement interferometer. The present method, however, will differ from all of these. In figure 1, L is a horizontal beam of white light from a collimator. After passing

through the auxiliary clear plate P (to be used preliminarily for parallelizing the mirrors of the system in a way presently to be shown), the beam is reflected at a and b by the half silver plates H_1 and H_2 respectively to the wide opaque mirror m. The rays now retrace their paths or nearly so to be in turn transmitted at a and b by the half silvers H_1 and H_2. These transmitted pencils similarly impinge on the opaque mirror M and the half silver H_3 at c and d respectively, and pass thence (the ray from c being transmitted) into the telescope at T. The direct vision grating-prism g may be swivelled in place or removed, at pleasure.

To bring the system of four mirrors into complete parallelism is here of considerable importance if the spectrum fringes or the residual phenomenon are to be adequately large for measurement. The presence of the common mirror m, however suggests the procedure. When the clear plate P is in place, the rays ae and bf on returning are also again reflected at a and b toward L and may be clearly seen in a telescope[4]

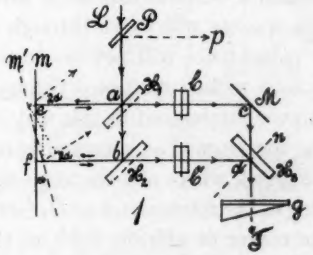


FIG. 1.

at p. Hence if m is the standard plane and nearly vertical, the mirrors H_1 and H_2 will be parallel when the slit images seen at p coincide horizontally and vertically, while H_1, H_2 and m will have their common normal plane in the diagram. In the same way the mirrors M and H_3 may be parallelized with their common normal plane in the diagram. If the distances ac and bd, ab and cd have previously been made nearly equal and the angles approximately 90°, the fringes will usually be found on moving the micrometer screw normal to H_3.

As the mirrors are thick glass plates it is preferable that the half silvered sides of H_1 and H_2 be toward L, and the half silvered side of H_3 toward M. In this case each ray passes the plates twice, as indicated in figure 1. With ordinary plate glass the fringes when found are still apt to be small. They are then to be enlarged and centered, by compensator of clear glass C and C', in the two rays respectively, rotated in opposite directions around a horizontal axis until the center of ellipses

is in the field of the spectroscope. It may be necessary to actuate the micrometer screw at d to complete the adjustment.

When the ellipses are centered, the direct vision spectroscope g removed, and the slit widened or removed, the residual or achromatic fringes appear in sight and are ready for use. These are always strong. The spectrum fringes are apt to be less so, since the parts of the ray L pass through two half silvered surfaces H_1H_2 or H_1H_3 in succession.[5] The spectrum fringes are sharp when the slit is fine. If the white residual fringes are too dazzling a single or two half silvers may be placed before the objective of the telescope with advantage. Two plates with their half silvered sides in contact and held so by a steel clip, are excellent for this purpose while they are at the same time protected from sulphur corrosion. This in fact is the best method of preserving silver mirrors (in pairs) when not in use.

When the spectra are in coincidence and the fringes sharp, the mirror m may be rotated around a vertical axis at A into some position, m'. In such a case the two spectra will move through the field of the telescope at T, but their coincidence will not be destroyed. The D lines, for instance, will continue to be superposed throughout. Considerable path difference is however introduced in this way and hence the fringes will march through the spectrum at an enormously more rapid rate. The following data may be given, where α is the angle of rotation of the mirror m and N the reading of the micrometer at H_3 (screw in the normal dn) necessary to bring the center of ellipses back to the sodium lines. In both cases the centers were out of the field (above or below), so that horizontal fringes were made the criterion for adjustment. This method is somewhat rough, but adequate for the present purposes.

1. Fine thin fringes. Relatively large differential glass path. Distance ab, figure 1, $2R = 21$ cm. Thickness of glass plates (half silvers) $e = .70$ cm.

$\alpha =$	0°	.05°	.20°	.30°	.40°	.50°	.60°
$N \times 10^3 =$	23	30	128	162	215	258	299 cm.

This is curve a in figure 2. From it the mean rate

$$\frac{\Delta N}{\Delta \alpha} = .47 \text{ cm/degree, or } 27 \text{ cm/radian}$$

may be found.

2. Coarse large fringes. Smaller differential glass path.

$\alpha =$	0°	.1°	.2°	.3°	.4°	.5°	.6°	.7°	.8°	.9°	1.0°
$N \times 10^3 =$	−25	+29	84	134	176	217	265	323	365	420	467 cm.

This is the curve given (with double ordinates for distinction), in curve *b*, figure 2, and in figure 3. Besides this the datum $\alpha = -.6°$, $N = -.320$ cm was obtained. In figure 3 the mean rate is

$$\frac{\Delta N}{\Delta \alpha} = .465 \text{ cm/degree, or } 26.6 \text{ cm/radian,}$$

agreeing with the preceding as closely as may be expected. We may thus estimate $\Delta N = 27 \times 10^{-6}$ of displacement at the micrometer at H_3 per micro-radian of turn α at the mirror m, which amounts to a little less than one interference ring per microradian (about one-fifth second of arc) of turn. The theory will be given later. With regard to the application to the electrometer we may come to the following

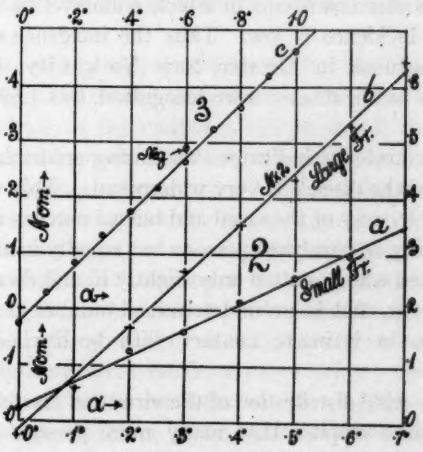


FIG. 2 AND 3.

conclusion. A good instrument of the quadrant or similar type should give about a radian of deflection per volt, or a microradian per microvolt. In the present interferometer the microradian is about equivalent to the passage of one interference fringe. Hence one fringe per microvolt is about the order of sensitiveness to be expected.

[1] This contribution is a note from a Report to the Carnegie Institution of Washington.

[2] *Washington, Carnegie Inst., Pub.*, No. 229, 1915, (¶ 10 et seq.)

[3] *Ibid.*, (¶ 67 et seq.)

[4] The return rays may also be projected in a screen near the objective of the properly focussed collimator and the sharp images put in contact.

[5] If α is the refraction of light transmitted and $1 - \alpha$ reflected, the fraction of the original light, L, reaching the telescope T will be $2\alpha^2(1 - \alpha)^2$. This is a maximum if $\alpha = \frac{1}{2}$. Thus the illumination is reduced to $\frac{1}{8}$.

MECHANISMS THAT DEFEND THE BODY FROM POLIOMYELITIC INFECTION, (a) EXTERNAL OR EXTRA-NERVOUS, (b) INTERNAL OR NERVOUS

By Simon Flexner

ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

Read before the Academy April 17, 1917

I am led to report the results of recent experiments looking toward the solution of the problem of susceptibility in epidemic poliomyelitis, by reason of the intrinsic interest of the subject and because of certain advances in knowledge which have been made recently.

The mass of the population appears insusceptible to the disease. That is to say even under conditions in which poliomyelitis is severely epidemic the real incidence is low. Thus the incidence during the past summer and autumn in Greater New York City, in which more than 9000 cases of the disease were recognized, was 1.59 per 1000 of the population.

Our present knowledge indicates that during epidemics, the microbic cause or virus of the disease is very widespread. This virus leaves and enters the body by way of the nasal and buccal mucous membranes. It is present not only in paralyzed persons but equally in the greater number of the affected who are often only slightly ill and do not develop any paralysis whatever, and in an undetermined number of healthy persons who have been in intimate contact with both classes of patients mentioned.

In view of the wide distribution of the virus and the relatively low case incidence, we must suppose that many more persons are exposed to than acquire the infection. Hence the body must possess defensive mechanisms usually sufficing to protect it from invasion.

Two sets of defences have been detected. The first or external consists of the secretions of the nasal and probably pharyngeal mucous membranes. Their action has been especially studied by Amoss and Taylor.[1] The secretions in many if not in most persons when left in contact for a relatively short time with the virus of poliomyelitis, inactivate or neutralize it. This test is readily made because monkeys are highly susceptible to inoculation with the virus. When an active virus has been mixed with the bacteria-free nasal secretions obtained by filtration through porcelain, it is no longer active for monkeys.

Some persons fail to yield this neutralizing nasal secretion; in others, a temporary, pathological state of the mucous membranes removes the inactivating property previously present. The number of tests is still

too small to determine whether young persons who are the more susceptible yield secretions which are numerically inferior in neutralizing power to those supplied by older persons.

Probably the failure of this external defensive measure is not in itself decisive, because of the existence of the second or inner defensive mechanism. It consists of the membranes about the brain and spinal cord and attached secreting organ of the choroid plexus. This meningeal-choroid complex is remarkably efficient in excluding from the cerebrospinal fluid, and hence from the substance of the brain and spinal cord, almost everything present in the circulating blood, except water and a few inorganic salts. The fluid is also almost free of cells. Only when the complex has been injured in some way and its integrity impaired does it permit even protein and cells to pass through from the blood into the cerebrospinal fluid.

The fact had previously been determined,[2] that the virus of poliomyelitis passes with great difficulty from the blood into the nervous organs, unless the choroid plexus and meninges had previously been injured, say through setting up an aseptic inflammation by injecting sterile horse serum into the meninges by means of lumbar puncture. What the present studies have brought out is the extraordinary sensitiveness of those structures to the injurious action of othewise bland fluids,[3] for not only is their permeability affected by irritants such as horse and even normal monkey serum, both of which produce visible signs of inflammation, but also by sterile physiological salt, Ringer's or Locke's solutions which set up only evanescent inflammatory changes, and of the cerebrospinal fluids from other monkeys which produce no detectable inflammatory changes whatever. The injury produced by the last fluid mentioned is so slight as possibly to be regarded in Cohnheim's sense as merely molecular.

Possibly poliomyelitis arises during the prevalence of the malady when both sets of defensive measures fail. This probably would occur only in exceptional instances in individuals among populations of any size. It is for the moment not difficult to conceive of reasons to account for the failure of the external mechanism, and more difficult to account for failure of the internal mechanism of defense. Not improbably the neutralizing power of the nasal secretions tends to reduce the carriage of the virus upon the nasal mucosa of persons exposed to and having suffered from infection with the virus of poliomeylitis. It becomes, therefore, an essential agency in diminishing public danger through reduction in the number of the potential virus carriers which arise.

There is one irritating fluid only so far detected which does not pro-

mote infection when injected into the cerebrospinal meninges. This fluid is an immune serum obtained from monkeys or human beings previously recovered from poliomyelitis. The immune serum carries neutralizing principles which inactivate the virus as it passes from the blood into the cerebrospinal fluid. This observation is in harmony with the curative action exercised by the serum, as was first shown some years ago in inoculated monkeys,[4] and has recently been confirmed for human cases of epidemic poliomeylitis.[5]

[1] Amoss, H. L., and Taylor, E., *J. Exp. Med.*, **25**, 1917, (507).
[2] Flexner, S., and Amoss, H. L., *Ibid.*, **19**, 1914, (411).
[3] Flexner, S., and Amoss, H. L., *Ibid.*, **25**, 1917, (525).
[4] Flexner, S., and Lewis, P. A., *J. Amer. Med. Assn.*, **54**, 1910, (1780); **55**, 1910, (662).
[5] Amoss, H. L., and Chesney, A. M., *J. Exp. Med.*, **25**, 1917, (581).

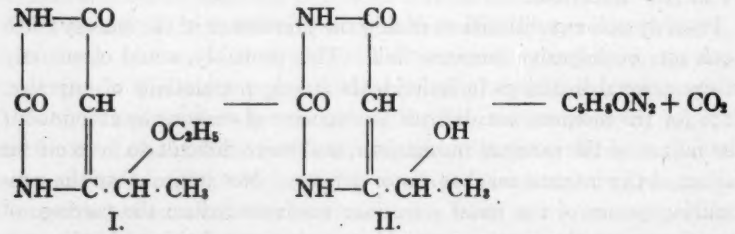
THE BEHAVIOR ON HYDROLYSIS OF THE SIMPLEST SECONDARY NUCLEOSIDE ON THYMINE

By Treat B. Johnson and Sidney E. Hadley

SHEFFIELD SCIENTIFIC SCHOOL, YALE UNIVERSITY

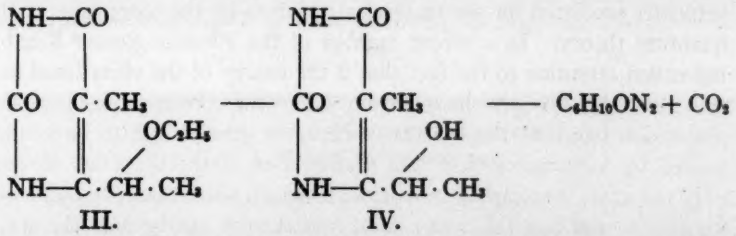
Communicated by L. B. Mendel, May 5, 1917

In a previous publication from the Sheffield Chemical Laboratory Johnson and Hadley[1] have shown that the ethyl ether of the secondary uracil-nucleoside I undergoes a very unique transformation when subjected to hydrolysis by heating with hydrobromic acid in aqueous solution. Ethyl bromide is first evolved with formation of the nucleoside II. This pyrimidine then undergoes a profound molecular change on prolonged heating and is transformed, with evolution of carbon dioxide, into a combination of unknown structure having the empirical formula $C_5H_8ON_2$.



Great biochemical interest is attached to nucleoside transformations of this character, and we have now in progress an investigation planned to establish experimentally the structure of this interesting product of hydrolysis.

We have now continued our investigation on the hydrolysis of pyrimidine-nucleosides and have examined the behavior towards acids of the ethyl ether of the corresponding secondary nucleoside of thymine III. This pyrimidine has already been synthesized and a description of the properties of the compound is given in a dissertation presented by Dr. Hadley in 1916.[2] We now find that this pyrimidine III interacts in a manner perfectly analogous to that shown by its lower homologue I. When heated under pressure with an aqueous solution of hydrochloric acid it is transformed as expected into the nucleoside IV with evolution of ethyl chloride. On continued heating, however, the nucleoside IV gradually breaks down with evolution of carbon dioxide, and is changed into a compound of unknown structure having the formula $C_6H_{10}ON_2$. The transformation is expressed by the following equation.



In other words, the two hydrolytic products $C_5H_8ON_2$ and $C_6H_{10}ON_2$ are combinations of the same order and are representatives of an homologous series differing in constitution by a CH_2 radical.

The compound $C_6H_{10}ON_2$ derived from the nucleoside ether III has a melting or decomposition point of 270°. We have subjected the combination to a complete analysis and have obtained the following analytical results. Carbon 56.88%, hydrogen 8.10% and nitrogen 21.96%. The theoretical values for these three elements respectively in a compound having the formula $C_6H_{10}ON_2$ are carbon 57.1%, hydrogen 7.9% and nitrogen 22.2%.

Our observation that pyrimidines of the type represented by formulas II and IV readily loose one of their carbon atoms is unique in that the change can be brought about by simple hydrolysis and without the employment of an oxydizing agent. The mother compounds from which the nucleosides are derived viz.: uracil and thymine, can be heated with acids at high temperatures for hours without destruction of the pyrimidine ring. The final results of our investigation will be published in the *Journal of the American Chemical Society*.

[1] Johnson and Hadley, *J. Amer. Chem. Soc., Easton, Pa.*, 38, 1916, (1844).
[2] Hadley, Sidney E., *Dissertation*, Yale University, 1916.

THE OCCURRENCE OF HARMONICS IN THE INFRA-RED ABSORPTION SPECTRA OF DIATOMIC GASES

By James B. Brinsmade and Edwin C. Kemble

JEFFERSON PHYSICAL LABORATORY, HARVARD UNIVERSITY

Communicated by E. H. Hall, May 1, 1917

The study of the infra-red absorption bands of gases has within the last few years received a great impetus through Bjerrum's[1] explanation of their structure as the result of the superposition of the molecular rotations on the vibrational motion of the charged atoms, which is the primary cause of the absorption. Bjerrum's suggestion was quickly followed by the discovery of v. Bahr[2] that these bands are, in reality, clusters of comparatively narrow lines, corresponding to the discrete angular velocities predicted for the molecular rotations by the older form of the quantum theory. In a recent number of the *Physical Review*[3] Kemble has called attention to the fact that if the energy of the vibrational motion also takes on only the quantum values the corresponding infra-red absorption bands in the spectra of diatomic gases ought to be accompanied by faint harmonics. An examination of the literature showed only one case, viz., carbon monoxide, in which more than one band was known to exist and this was a faint one at very nearly half the wave length of the fundamental. The present article is a preliminary report on an experimental search for similar harmonics in the infra-red absorption spectra of other diatomic gases and an examination of their structure. First harmonics have been found in the spectra of hydrochloric acid and hydrobromic acid and their structure as well as that of the faint carbon monoxide band has been shown to be in general agreement with the theory. Search was also made for possible second and third harmonics in the spectra of carbon monoxide and hydrochloric acid, but without result.

Apparatus and Method of Procedure.—The work was done on a prism spectrometer with a combination Wadsworth-Littrow mounting similar to that described by Gorton.[4] This arrangement gives an unusually high resolving power by a double passage of the energy through the prism. The energy was measured with a thermopile. The prism was of quartz, the refractive indices given by Carvallo and Rubens[5] being used in computing the wavelength scale. The absorption tube was 78 cm. long and had a minimum inside diameter of 3.5 cm. The ends were closed with windows of fused quartz.

Each galvanometer deflection with the absorption tube in place was 'sandwiched' between two deflections with the tube drawn to one side.

In this manner a curve was obtained, showing the transmission of the tube relative to an air path of equal length. The absorption in the gas was computed by comparing the transmission curve for the tube when evacuated with that when filled with the gas under investigation. From two to six complete sets of observations were taken at each spectrometer setting.

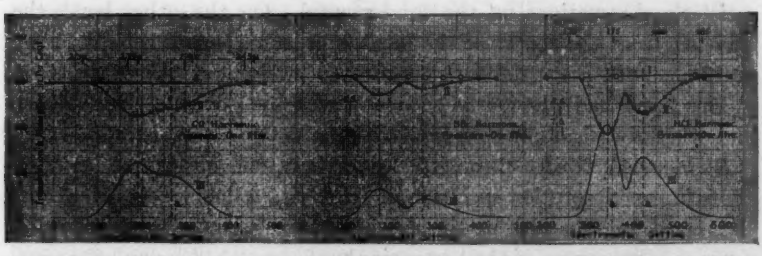


FIG. 1. FIG. FIG. 3.

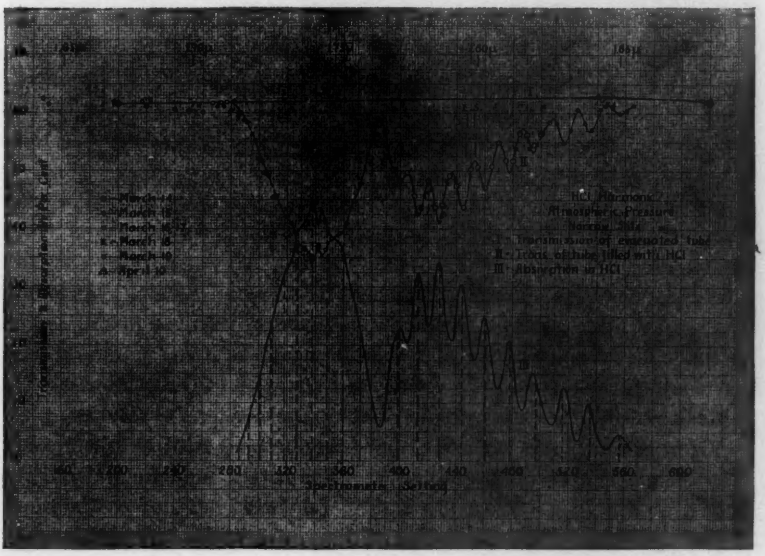


FIG. 4.

Carbon Monoxide.—According to Burmeister[6] the principal infra-red absorption band of CO is a doublet whose maxima are at 4.60 μ and 4.72 μ. The center of the harmonic should accordingly be at 2.33 μ. It should be a doublet with one fourth the wavelength difference between the maxima that is observed in the fundamental. Figure 1 shows the

absorption curve obtained. When this curve was taken the spectrometer was not properly adjusted to give its full resolving power. However, it is easy to see that the band is actually a doublet and that within the limits of error of our observations the separation of the maxima of the components is that predicted. The vertical lines *a-a* in the figure have the wavelength separation predicted for the maxima from Burmeister's observations on the fundamental. On the other hand, the wavelength of the center of the band is greater than it should be by 0.043 μ.

This band had previously been observed by Coblentz, Burmeister, and others, but had not been resolved into its two components.

Hydrobromic Acid.—Burmeister gives only one absorption band in the infra-red absorption spectrum of HBr, viz., a doublet with maxima, (corrected for slit-width by the Paschen-Runge formula) at 4.013 μ and 3.836 μ. The center of the harmonic should be at 1.962 μ and the separation of the maxima should be 0.0442 μ. Figure 2 shows the absorption curve obtained. The widths of the entrance slit and thermopile slit are indicated by two pairs of short vertical lines marked E. S. and T. S. respectively. The distance between the maxima is in satisfactory agreement with the theoretical distance (cf. vertical lines *a-a*). As in the case of CO the wavelength of the center of the band is greater than that expected, the error being 0.026 μ.

Hydrochloric Acid.—The infra-red absorption spectrum of HCl consists, according to Burmeister, of a single doublet with maxima (corrected for slit-width) at 3.394 μ and 3.557 μ. We have found an additional doublet (fig. 3) with maxima at 1.783 μ and 1.742 μ. As in the cases of the other gases examined the observed wavelength of the center of the band is somewhat greater than it should be if the band is a true harmonic of the one at 3.475 μ, but the separation of the maxima agrees with the theoretical value predicted from Burmeister's observations.

Figure 4 shows this same HCl band as observed with narrower slits. The quantum lines discovered by v. Bahr in the fundamental are resolved on the long wavelength side of the band but not on the short wavelength side. The reason for the asymmetry in the positions of the quantum lines will be discussed below.

Figure 5 shows the fundamental as observed when the tube was filled with a mixture of air and HCl, the latter having a partial pressure of 20.3 cm. The absolute magnitudes of the absorption shown by this curve have not been determined as accurately as we hope to determine them in the future, but the positions of the bands are probably to be relied on. The wavelength of the center of this band is less than that observed by Burmeister with a prism by 0.01 μ.

Discussion.—According to the theory previously referred to,[3] the infra-red absorption spectrum of a diatomic gas at moderate temperatures should consist of a relatively strong fundamental doublet accompanied by a faint harmonic. The latter band should also be a doublet and the wavelength difference of the components should be one fourth of the wavelength difference of the components of the fundamental. The theory applies to five gases, viz., CO, NO, HCl, HBr, and HI. Of these we have examined three, and in each case the prediction of the theory has been verified. The only discrepancy between theory and observation consists in a slight excess in the observed wavelengths of the 'harmonics' over their computed values, amounting to 0.043 μ, 0.026μ, and 0.025 μ, in the cases of CO, HBr, and HCl respectively.

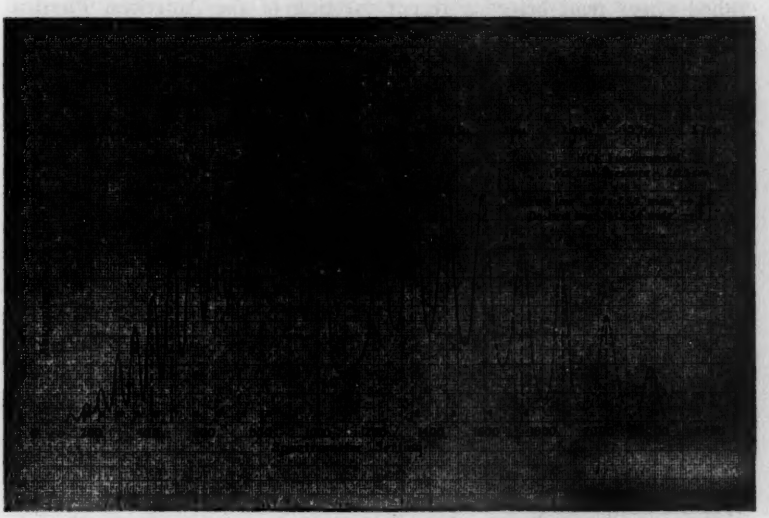


FIG.

This disagreement may be attributed to a slight error in the dispersion curves on which the wavelength measurements are based. As no absorption bands other than those here mentioned are known in the near infra-red spectra of the gases investigated, it seems out of the question that the occurrence of these weak bands at wavelengths so near the computed values can be a matter of chance. Moreover, as these diatomic molecules have but one vibrational degree of freedom, it would be difficult to explain the occurrence of two absorption bands in the infra-red spectra of these gases except as the result of the non-simple harmonic character of motion of the two atoms along their line of centers. That the faint bands are not due to impurities is proved by the spacing of the maxima

of the two components. We therefore look upon the small wave length discrepancy referred to as an indication of a slight error in the accepted values of the infra-red refractive indices of quartz.

The Asymmetry of the Bands.—According to the elementary theory of the structure of the infra-red absorption bands of diatomic gases given by Bjerrum[1], the curve obtained when absorption coefficients are plotted against frequency should be a symmetric doublet, of which each half should have the form of the distribution function for angular velocities. He assumes implicitly that the frequency of the atomic vibration is independent of the angular velocity of the molecule. The observed absorption bands are all asymmetric, however, the high frequency component being narrower and more intense. In an unpublished paper read before a recent meeting of the American Physical Society by Kemble[7], it was suggested that this asymmetry might be due to the fact that the frequency of the atomic vibration is lowered by the expansion of the molecule under the influence of the centrifugal force produced by the molecular rotation. This change of frequency would cause a crowding together of the quantum lines in the high frequency component and a corresponding increased separation in the low frequency component. On the basis of this theory the frequency of vibration should be

$$\nu = \nu_0 - a\nu_r^2$$

where a is a constant, ν_0 is the frequency of vibration for zero angular velocity, and ν_r is the frequency of rotation. Combining this assumption with the quantum theory we obtain the following formula for the positions of the two elementary lines corresponding to the pth unit of angular velocity.

$$\nu = \nu_0 \pm p\nu_1 - ap^2\nu_1^2.$$

ν_1 is the unit of angular frequency. The dashed vertical lines on figure 4 indicate the theoretical positions of the quantum lines in the HCl harmonic as computed by the above formula, using the values 3.7×10^{-14} and 6.32×10^{11} for a and ν_1 respectively. The vertical lines in figure 5 give the corresponding positions for the fundamental, using the values 2.55×10^{-14} and 6.32×10^{11} for a and ν_1. In each case the agreement is satisfactory.

The unit of angular frequency, ν_1, is inversely proportional to the moment of inertia of the molecule and v. Bahr interpreted an apparent decrease in the value of ν_1, for the larger values of p which was observable on her absorption curve for the HCl fundamental, as an indication of an increase in the moment of inertia with increasing angular velocity. It will be observed that our observations show no perceptible variation in the value of ν_1.

One difficulty arises in connection with this theory of asymmetry. If the faint HCl band is a true harmonic of its strong companion the constant a should have twice the value for the former that it does for the latter. According to our observations the ratio of the two values of the constant is about 1.5 instead of 2. However, a very slight change in the assumed form of the dispersion curve in the neighborhood of 3.5 μ would suffice to bring the observations on the two bands into agreement. As a matter of fact the shape of the dispersion curve in this region is somewhat uncertain, for the points determined by Rubens are far apart and slightly irregular. The wavelength scale shown in figure 5 was obtained by drawing the best possible *smooth* curve through the points given by Rubens.

Kinetic Energy at the Absolute Zero.—Figures 4 and 5 emphasize an extremely important fact already evident in v. Bahr's absorption curve for the HCl fundamental, viz., the absence of a central band corresponding to a group of molecules having zero angular velocity. This observation forces the conclusion that none of the molecules are without rotational energy and brings us to a combination of the first form of Planck's quantum theory with the zero-point energy hypothesis which has hitherto been associated with the second form of his theory. Additional evidence in favor of this view including a discussion of the specific heat of hydrogen will be published shortly.

Conclusion.—The complete verification of a natural theory of the asymmetry of the infra-red absorption bands of diatomic gases and the accompanying explanation of the apparent increase in the moment of inertia of the molecule with increasing angular velocity clear up the outstanding difficulties in the theory of the structure of these bands. Consequently there can be no further doubt that it is correct to conclude from the discontinuities in their structure that the angular velocities are distributed among the molecules in the discontinuous manner predicted by the older form of the quantum theory. The proved existence of harmonics in the infra-red spectra of the same gases is almost equally good evidence that the vibrational energy of these molecules is distributed in the same manner.

[1] Bjerrum, N., *Nernst Festschrift*, Halle, 1912; *Berlin, Verh. D. physik. Ges.*, **16**, 1914, (640).

[2] v. Bahr, Eva, *Berlin, Verh. D. physik. Ges.*, **15**, 1913, (1150); *Phil. Mag., London*, **28**, 1914, (71).

[3] Kemble, E. C., *Physic. Rev., Ithaca, N. Y.*, (Ser. 2), **8**, 1916, (701).

[4] Gorton, A. F., *Ibid.*, **7**, 1916, (66).

[5] Landolt and Börnstein, *Physikalisch-Chemische Tabellen*, Berlin, 1912, p. 972.

[6] Burmeister, W., *Berlin, Verh. Dh. pysik. Ges.*, **15**, 1913, (589).

[7] Kemble, E. C., The Infra-Red Absorption Bands of Gases and the Application of the Quantum Theory to Molecular Rotations. New York Meeting of Amer. Phys. Society, Dec. 28, 1916.

THE LOSS IN ENERGY OF WEHNELT CATHODES BY ELECTRON EMISSION

By W. Wilson

RESEARCH LABORATORIES OF THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY AND OF THE WESTERN ELECTRIC COMPANY

Communicated by R. A. Millikan, May 9, 1917

It was first shown by O. W. Richardson in 1903 that the thermionic current from a hot cathode is given by the equation $i = a\theta^{\frac{1}{2}}e^{-b/\theta}$ where θ is the absolute temperature and a and b are constants.

The constant b has the special significance that it is proportional to the work done by an electron in leaving the surface of the body in question. This work can be determined directly by measuring the difference in power required to maintain a body at a certain temperature when it is emitting electrons from when it is not. Richardson and Cooke and later Lester have obtained values for tungsten which are in very good agreement with the values of b obtained by Langmuir and K. K. Smith.

On the other hand Wehnelt and Jentsch, Schneider, Wehnelt and Liebreich, and Richardson and Cooke have all found that for lime covered cathodes either the effect is so small in comparison with other energy changes as to be completely masked or that there is no correspondence between the two quantities.

Since these experiments suggest that the mechanism of thermionic emission from Wehnelt cathodes is different from that for pure metals further experiments were made by the author to determine whether consistent results could be obtained by using more stable cathodes.

If W is the work done by an electron in leaving the surface of a hot body $W = bR$, where R is the gas constant for one molecule.

If it is assumed that the work done by the electron is that done by moving through a double layer of strength ϕ we have $W = \phi e$, and $\phi = bR/e$.

The method of Richardson and Cooke was used for the direct determination of ϕ. The constant b was determined in the usual manner, thermionic current being measured with the cathode at different temperatures which were obtained by means of an optical pyrometer of the Holborn and Kurlbaum type.

The following are the results obtained:

FILAMENT NUMBER	B DEGREES	$\frac{bR}{e}$ VOLTS	ϕ VOLTS
1	27,200	2.34	2.39
2	30,100	2.59	2.54
3	23,500	2.02	1.97
4	25,200	2.16	2.28
5	38,200	3.28	3.22
6	40,600	3.49	3.45

Filaments 1 and 2 were coated with BaO 50%, SrO 25%, CaO 25%, Filaments 3 and 4 with BaO 50%, SrO 50%, and Filaments 5 and 6 with CaO alone.

It appears that for Wehnelt cathodes the values ϕ and bR/e show a good correspondence. This is a strong point in favor of the view that the emission of electrons from Wehnelt cathodes is due to a similar mechanism to that causing the emission from heated pure metals. It is also a further proof of the substantial correctness of Richardson's hypotheses to account for the emission of electrons by hot bodies.

DAILY VARIATION OF WATER AND DRY MATTER IN THE LEAVES OF CORN AND THE SORGHUMS

By Edwin C. Miller

KANSAS AGRICULTURAL EXPERIMENT STATION

Communicated by R. Pearl, May 14, 1917

In connection with the study of the water relations of corn and the non-saccharine sorghums previously reported by me (*J. Agric. Res.*, 6, 1916), it was thought advisable to determine the daily variation of the water and dry matter in the leaves of these plants. A knowledge of the variation of the water in the leaves should throw some light on the relative ability of these plants to absorb water from the soil and to transport it to regions of loss from transpiration, while a study of the daily variation of dry matter in the leaves would permit a comparison of the relative power of the plants to manufacture food under different climatic conditions. The experiments herein reported were conducted during the summers of 1914, 1915, and 1916 at the State Branch Experiment Station at Garden City, Kans.

Cultural Methods.—The plants used in these experiments were Pride of Saline corn, Blackhull kafir and Dwarf milo. In 1914 and 1915, the plants were grown in alternate rows on the same plot, while in 1916 the experiments were made with plants grown on a series of one twentieth acre plots. The plants were grown in a sandy loam soil that had been

fall plowed and irrigated with approximately 8 inches of water. The crops were surface planted in rows 44 inches apart. After the plants were a few inches high the corn was thinned to a distance of 2 feet between the plants, Blackhull kafir to 1½ feet and the Dwarf milo to 1 foot. The plots were scraped with a hoe to keep the weeds down but no other cultivation was given during the growing season. The plots received no water after the fall irrigation, except that which came from the rainfall.

Leaf Sampling.—The amount of water and dry matter in the leaves of a given variety of plant was determined every two hours from 30 leaf samples, each with an area of 1 sq. cm. Thirty representative plants of each variety were selected and a leaf chosen on each plant for furnishing all the samples for an experiment extending over the desired length of time. At 7 a.m. a single sample was taken from each of the 30 selected leaves toward their tips. This was done by means of a Ganong leaf punch with an area of one square centimeter. At 9 a.m. a sample was taken from each of the 30 leaves directly opposite the sample taken at 7 a.m. At 11 a.m. the samples were collected from the leaves directly below those taken at 7 a.m. and then at the next two hour period directly opposite these and so on. The samples for a forty-hour experiment were thus obtained from a portion of the leaves representing less than 6 inches of their respective lengths. The leaf samples from corn, kafir and milo at any period could be collected in the manner described in from five to eight minutes. Care was taken in the selection of the leaves, so that they would be as nearly the same age as possible for the three plants. The uppermost, fully-developed leaf of each plant was the one from which the leaf samples were obtained.

The samples were collected in weighed vials which were then quickly stoppered. The vials containing the moist material were weighed at once on balances sensitive to one tenth milligram. They were then placed in a drying oven at 100–105°C. until all the moisture was driven off. After drying, the samples were cooled in a desiccator over sulphuric acid and weighed so that the amount of water and dry matter could be obtained.

Results.—Nine experiments were conducted in 1914, two in 1915 and four in 1916. Four of the experiments in 1914 extended only through the daylight hours but all of the other experiments ranged in length from twenty-four to forty hours. In all the amount of water and dry matter in the leaves was determined every two hours for twenty-two days and ten nights. The amount of water in the leaves at any period of the night could be accurately determined owing to the fact that dew is very

rare during the summer in this portion of the Great Plains. Corn, kafir, and milo were used in all the experiments with but two exceptions in 1916. In these two experiments only corn and milo were used. The amount of water in the leaves was determined in grams per square meter of leaf; percentage on a wet basis and dry basis for each two hour period of the experiment. The amount of dry matter was determined in grams per square meter of leaf and in percentage of the moist weight of the leaf.

The leaves of milo contained less water at all times than the leaves of either corn or kafir at the same stage of development. The average water content per square meter of leaf for all the observations made was 111.4 grams for milo, 123.2 grams for corn and 126.3 grams for kafir. The amount of water in the leaves of corn and kafir was practically the same at like stages of growth. The small difference between the average amount of water in the leaves of kafir as compared with those of corn, is due to the fact that in one experiment in 1914 and in two experiments in 1916, the leaves of the kafir were about ten days younger than those of the corn and, as a consequence, contained a greater amount of water.

Under the conditions of these experiments, the leaves of corn in most cases were wilted during the greater portion of the day. The first signs of wilting were most generally observed between 9 a.m. and 10 a.m. and in most cases no visible wilting could be observed after 4 p.m. The kafir leaves wilted during the day, but not to the extent that the leaves of the corn did while the milo leaves showed little or no signs of wilting. Under these conditions the average range between the maximum and minimum amount of water per square meter of leaf during the two hour periods from 7 a.m. to 7 p.m. was 13.8 grams for corn, 8.4 grams for kafir and 7.8 grams for milo.

Table 1 shows the average gain or loss of leaf water during each two hour period of the day from 7 a.m. to 5 p.m. for the experiments conducted in 1914, 1915 and 1916. The average gain or loss for each period is expressed in grams per square meter of leaf and in percentage based on the water in the leaf at the beginning of the two hour period.

A consideration of the loss of the leaf water during the day shows that from 7 a.m. to 9 a.m. the rate of loss was practically the same for corn and milo and the least for kafir. From 9 a.m. to 11 a.m. as the aerial conditions became more severe, the rate of loss increased for corn and kafir, but decreased almost one half for milo. During the next two hours the rate of loss decreased for all three plants, but the rate of loss was approximately twice as great for corn and kafir as for milo. From 1 p.m. to 3 p.m. the rate of loss continued to decrease, while the rate of loss of

TABLE 1

SUMMARY OF THE VARIATION OF THE WATER CONTENT OF THE LEAVES OF CORN KAFIR AND MILO DURING THE YEARS 1914, 1915 AND 1916 AT GARDEN CITY, KANSAS

TIME	PLANTS	LOSS			GAIN			NET GAIN OR LOSS	
		Number of cases of loss	Average loss of leaf water per square meter of leaf	Average per cent of loss based on leaf water at beginning of period	Number of cases of gain	Average gain of leaf water per square meter of leaf	Average per cent of loss based on leaf water at beginning of period	Per square meter of leaf	Per cent based on leaf water at beginning of period
			grams			grams		grams	
7 a.m.– 9 a.m...	Corn	21	4.1	3.5	0	0	0	4.1 loss	3.5 loss
	Kafir	15	3.3	2.8	1	3.8	3.2	3.0 loss	2.5 loss
	Milo	18	4.2	4.0	3	1.3	1.3	3.6 loss	3.4 loss
9 a.m.–11 a.m...	Corn	18	4.8	4.2	2	2.5	2.2	4.1 loss	3.8 loss
	Kafir	16	3.9	3.4	1	1.3	1.0	3.7 loss	3.4 loss
	Milo	20	2.2	2.1	1	5.2	5.6	1.9 loss	1.8 loss
11 a.m.– 1 p.m...	Corn	15	3.7	3.4	6	2.9	2.4	2.5 loss	2.2 loss
	Kafir	14	3.1	2.8	3	4.2	3.6	2.5 loss	2.2 loss
	Milo	13	1.9	1.9	7	1.7	1.6	1.1 loss	1.1 loss
1 p.m.– 3 p.m...	Corn	10	3.1	2.8	10	2.5	2.2	1.8 loss	1.6 loss
	Kafir	4	2.5	2.1	13	3.1	2.7	2.0 gain	1.7 gain
	Milo	11	3.3	3.3	10	2.6	2.5	1.7 loss	1.6 loss
3 p.m.– 5 p.m...	Corn	4	2.7	2.3	17	5.7	4.9	4.6 gain	4.0 gain
	Kafir	0	0	0	17	4.3	3.6	4.3 gain	3.6 gain
	Milo	4	4.1	4.2	17	3.9	3.7	3.2 gain	3.0 gain

milo increased over one per cent. These results seem to indicate that the absorption of water by the milo from the soil and its translocation to leaves, was proceeding more rapidly in proportion to the loss of water from the plant than in the case of either corn or kafir. The fact that the leaves of milo seldom wilted during the day also indicated that fact. The wilting of the leaves of milo in contrast to either the corn or kafir usually could not be observed until much later in the day. The increase in the rate of loss of leaf water in the milo from 1 p.m. to 3 p.m. would indicate, that the rate of absorption of water from the soil during that period, was less than the loss by evaporation from the leaves.

The amount of dry matter in the leaves of milo was at all times greater than in the leaves of corn or kafir of the same age. Taking the average weight of a square meter of corn leaf as 1, the average weight of an equal area of leaf would be 1.08 for kafir and 1.16 for milo. These differences in weight could be due either to the more compact arrangement

of the cells, or to a difference in the thickness of the leaves of the three plants or to both of these factors.

The average difference between the maximum and minimum amount of dry matter in the leaves during the day from 7 a.m. to 7 p.m. was 4 grams for corn, 4.8 grams for kafir and 8.0 grams for milo. Table 2 shows the rate of increase in dry matter for corn, kafir and milo in grams per square meter of leaf for each of the two hour periods during the day, from 7 a.m. to 5 p.m.

TABLE II

AVERAGE RATE OF INCREASE OF THE DRY MATTER FOR EACH SQUARE METER OF LEAF FOR CORN, KAFIR AND MILO DURING EACH TWO HOUR PERIOD OF THE DAY

PLANT	A. M.			P. M.	
	7-9	9-11	11-1	1-3	3-5
	grams	*grams*	*grams*	*grams*	*gram*
Corn	2.2	1.1	0.8	0.7	0.8
Kafir	1.7	1.2	0.7	1.2	0.7
Milo	1.3	1.5	2.2	2.0	0.8

Two explanations are possible for these results. The milo plant either manufactures food in the leaves more rapidly than the corn or kafir, or the rate of translocation is higher in the latter plants. In most cases, under the conditions of these experiments, the leaves of corn were badly wilted during the greater portion of the day. The kafir leaves also wilted but not to the extent of the corn, while the leaves of milo very seldom showed signs of wilting. The smaller increase in dry matter in the leaves of corn and kafir during the greater portion of the day in comparison to the leaves of milo is evidently due to the severe climatic conditions. The high evaporation of water from the leaves of corn and kafir exceeds the intake by the roots and as a consequence, the water content is lowered to such an extent as to interfere with the vital processes of the protoplasm. The rise in temperature of the leaves due to the decreased transpiration may also be a factor in lowering the photosynthetic power of these plants.

The results indicate that under the conditions of these experiments, the sorghums and more particularly milo, can absorb water from the soil and transport it to the leaves more rapidly in proportion to the loss of water from the plant than can corn. As a result of this ability the sorghums can produce more dry matter for each unit of leaf area under severe climatic conditions than can the corn plant.

Further details are given in the *Journal of Agricultural Research*, 1917.

NOTE ON COMPLEMENTARY FRESNELLIAN FRINGES

By Carl Barus

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Communicated May 9, 1917

Measurement of Small Angles without Auxiliary Mirror.—This method makes use of the original apparatus heretofore described, but the two mirrors M and M' or N and N', figure 1, are rotated together as a rigid system around a vertical axis, at A for instance. In view of the absence of auxiliary reflection, the method will be but half as sensitive as the preceding one, so that the equation

$$R\Delta\alpha = \Delta N \cos i$$

is sufficient to approximately express the results. But on the other hand, if spectrum fringes are to be observed, there is greater abundance of light since the half silver film is penetrated but once by each component, *ac* or *bd*. When the achromatic fringes are used however the light is always superabundant and must be reduced in intensity. To try this method the mirrors N and N' were mounted on a good divided circle so as to rotate together on a rigid arm over a small angle α. The achromatic fringes displaced in this way were restored by advancing the mirror M' over the distance ΔN along the normal micrometer screw at n'. The following is an example of the results of corresponding values of ΔN and $\Delta\alpha$, when the distance apart of the rays *ac* and *bd* was $2R = 7$ cm.

$\alpha =$	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°	1.0°
$\Delta N \times 10^3 =$	0.0	8.0	16.6	35.6	34.9	42.7	50.7	61.7	70.5	78.5	90.6 cm.

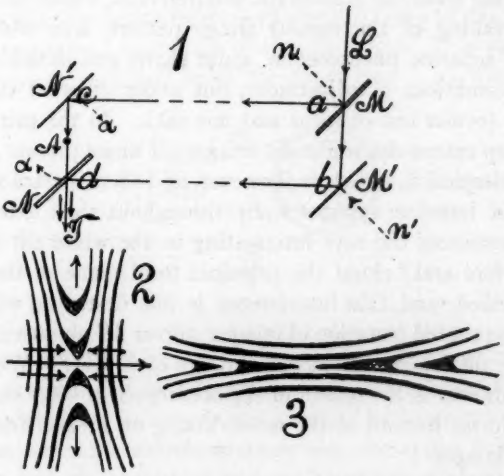
These results as a whole are much smoother than the earlier ones, for incidental reasons. From a graphic construction the mean rate $\Delta N/\Delta\alpha = 0.088$ cm/degree or 5.0 cm/radian may be obtained. Hence since $2R = 7$ cm., $(\Delta N/\Delta\alpha)2/R = 0.013$ in terms of degrees or 0.72 in terms of radians. This result is roughly half that in the preceding paper, if incidental errors be disregarded. From the above equation since $i = 45°$ nearly,

$$\frac{\Delta N}{\Delta\alpha} = \frac{2R}{2\cos i} = \frac{7.0}{1.41} = 5.0$$

agrees closely with the experimental result.

Complementary Fringes—Attention was now given to the hyperbolic fringes of a fine slit and white light, observed in the telescope at T when the ocular is drawn outward or to the rear of its position for the principal

focus and the spectroscope is removed. They appear and widen with the washed image of the slit. They are quite strong and sharp throughout and gorgeously colored, the fields and shades figure 2 being nearly complementary in color. The spectrum fringes must be centered if the others are to occur. The former (fig. 3) are usually long ellipses or hyperbolic with the major axis horizontal, while the corresponding new fringes (fig. 2) are hyperbolic with their major axis vertical. They are extremely sensitive to rotation of the micrometer mirror about a horizontal axis, rising or falling, but they soon vanish. When the micrometer mirror M' is rotated around a vertical axis, an operation which separates the white slit images in the telescope if originally coincident, the new fringes move bodily by displacement, from left to right, or the



reverse, depending on the sign of the rotation, while they continually change their color scheme. When the design is thus displaced as a whole the individual fringes move as shown in figure 2. As a group the fringes closely resemble the lemniscates of a binaxial crystal in polarized light. The variation of the color scheme is probably the same since with homogeneous light (sodium) the design is in yellow and black. The pattern is not quite dichroic but appears so, red-green, blue-yellow combinations with intermediate violet-yellowish succeeding each other. In polarized light the figures are sharpened as a whole, but there is no discrimination. The pattern gradually vanishes with a wide slit, whereupon the achromatic fringes may be seen when the ocular is restored to the principal focal plane.

If the white slit images in the telescope pass through each other (in consequence of the rotation of M' about a vertical axis, as specified) the direction of fringes *twice* changes sign in rapid succession and this probably occurs when the white slit images are coincident. Barring this inversion, the march is regular and proportional to the rotation.

With the displacement (ΔN) if the mirror M' on the micrometer screw normal to its face, the fringes pass through a continuous succession of color schemes, but soon vanish; for they coincide in adjustment with the centered spectrum fringes. Similarly if a pair of mirrors (MM' or NN' (fig. 1)) rotates about a vertical axis as a rigid system, the same continuous change of color scheme and evanescence is apparent.

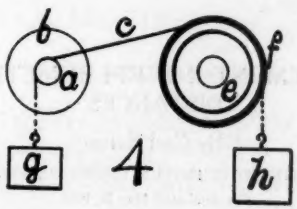
These interferences differ, naturally, from the spectrum interferences; they also differ from the achromatic interferences, which are much finer fringes, partaking of the regular fringe pattern seen with biprisms. They are a separate phenomenon, quite sharp and definite, occurring under like conditions of adjustment, but under different conditions of observation (ocular out of focus and fine slit). In the principal focus the two sharp extremely bright slit images are alone present. They are absolutely identical in structure, however, and their spectra when superposed would interfere symmetrically throughout their extent. Under these circumstances the rays intersecting in the white slit images also interfere before and behind the principal focal plane of the telescopic images specified, and this interference is not destroyed when the slit images are separated (rotation of opaque mirror M' about vertical axis), or when the slit images are passed through each other. What is not at once seen however is the reason of the occurrence of large sharp definite hyperbolic forms instead of the usual Young or Fresnel fringes of two slits or slit images.

On the Michelson interferometer these fringes (like the achromatic fringes) are extremely faint and can hardly be detected except by putting them in slow motion. The spectrum fringes are equally strong in all cases. It appears therefore that the two half silvers are favorable to evolving both the hyperblic and the achromatic set of fringes. The Michelson design is thus not useful here, nor for the measurement of small angles of rotation by the methods described, as the mirrors would have to be rotated in opposite directions.

Further work with the complementary fringes on different interferometers of the Jamin type showed that to produce the hyperbolics, the fine slit images must coincide horizontally and vertically. They do not in this case probably coincide in the fore and aft direction; for the plates, etc., were not optically flat. When the slit images are separated at the

same horizontal level into two fine parallel lines, the complementary fringes in fact become Fresnellian fringes, finer as the slit images are more separated and as the ocular is more rearward or forward. This is precisely what should occur. We may conclude therefore that the complementary fringes are Fesnellian interferences of two slit images and that the central hyperbolic forms are due to outstanding front and rear positions of the two slit images, which seem to coincide in the field of the telescope. Differentiated from these, the achromatic fringes are referable to the colors of thin plates. I have in fact since succeeded in obtaining the complementary fringes in the shape of broad straight gorgeously colored vertical bars, without suggestion of hyperbolic contour.

An attempt was made to get quantitative estimates of the passage of fringes, on rotating the paired mirrors NN' over an angle α. To control the small angles the device figure 4 was improvised and did good service. Here e is the tangent screw of a 6″ divided circle. It is surrounded by a snug anulus of cork and holds the brass ring f, on whose surface a



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coarse screw thread has been cut. Near this and with its axis in parallel is a $\frac{1}{4}$ inch screw a and socket (not shown), controlled by the disc b. A strong linen thread c is looped once around f in the grooves of the screw and once or twice around the grooves of a, the string being normal to the cylinders and kept taut by two small weights, g, about a half ounce and h, about an ounce. The head b may be turned either way and the angle read off in minutes on the head of the tangent screw e.

The theoretical value apart from glass paths and other corrections should be, per fringe vanishing

$$2R\Delta\alpha = \lambda$$

where R is the radius of rotation corresponding to the angle $\Delta\alpha$ and λ the mean wave length of light. In the given adjustment $2R = 10$ cm. was the normal distance apart of the two interfering beams. Hence

$$\Delta\alpha = \frac{\lambda}{2R} = \frac{60 \times 10^{-6}}{10} = 6 \times 10^{-6} \text{ radians or } 1.2''.$$

per vanishing fringe. As the change of glass path of one beam would have to be deducted from $2R$, a somewhat larger value would be anticipated. Testing the complementary fringes (white light) the passage of about 25 fringes completed the phenomenon after which it paled to whiteness. These 25 fringes passed within $\Delta\alpha = 0.75'$, or per fringe about $0.03'$ or $1.8''$ of arc. Of course this is merely an estimate from the small angles of turn involved.

The complementary fringes with sodium light are available indefinitely. I counted about 100 fringes for an angle of $2.7'$, i.e., $1.6''$ per fringe.

Finally using the spectrum fringes of the spectroscope, about 120 fringes were counted within $3'$, i.e., $1.5''$ per fringe. All of these values are larger than the computed value $\lambda/2R$ without correction, but in view of the large number of fringes within exceedingly small angle $\Delta\alpha$, sharp agreement is not to be expected.

[This note is from a Report to the Carnegie Institution of Washington, now in preparation.]

THE DISPLACEMENT INTERFEROMETRY OF LONG DISTANCES

By Carl Barus

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Communicated, May 22, 1917

1. *Small Angles.*—In my preceding notes I suggested two methods for the measurement of small angles. The first used an auxiliary mirror and apart from corrections the angle $\Delta\alpha$ over which the auxiliary mirror turns is

$$\Delta\alpha = \Delta N \cos i/2R \qquad (1)$$

where ΔN is the displacement of one of the plane mirrors parallel to itself necessary to restore the achromatic fringes to their former position in the field of the telescope, i the angle of incidence (conveniently 45°), $2R$ the normal distance apart of the (parallel) interfering pencils in the fore and aft direction of the incident beam. In the second method the auxiliary mirror is dispensed with and the rotation of a rigid system of paired mirrors is used. The sensitiveness is half the preceding.

2. *Distances.*—Suppose now that the paired mirrors near the telescope confront but a part of the area of the objective and that the telescope can therefore look over the mirrors directly into the region beyond. (A series of small mirrors or reflecting prisms may be employed

to the same purpose; or the mirrors may both be half silvered and transparent.) The telescope now contains two images, the first due to rays (K) entering it directly, the second due to rays (L) reflected into it by the mirrors of the interferometer. Suppose the object seen lies at infinity like a star, that its two images are made to coincide by adjusting the angle α, and that the achromatic fringes have been brought into the field by adjusting the micrometer displacement N.

Now let the angle α be changed by $\Delta\alpha$ until the two images of an object M, at a measurable distance d, coincide. Displace the micrometer mirror by ΔN until the achromatic fringes are restored to their former position. Let b be the effective distance apart of the paired mirrors in the direction right and left to the observer or transverse to the impinging rays (L) and finally s the angle at the apex of the triangle of sight on the base b; i.e. the small angle between the present rays KL. Then

$$d = b \cos g \quad s = b \cos g \quad 2\Delta\alpha = b/2\Delta\alpha \tag{2}$$

(nearly) by the laws of reflection. Hence from equation (1)

$$d = bR/\Delta N \cos i \tag{3}$$

Here $2bR$ is the area of the *ray parallelogram* of the interferometer. Using the constants of my apparatus, let $i = 45°$, $R = 10$ cm., $b = 200$ cm., $\Delta N = 10^{-4}$ cm., the latter being the smallest division on the micrometer. Hence

$$d = 200 \times 10/10^{-4} \times 0.71 = 2.8 \times 10^{7} \text{ cm.} = 280 \text{ kilometers.}$$

or about 170 miles is the limit of measurement of the apparatus.

3. *Performance.*—Again from equation (3) the sensitiveness $\delta(\Delta N)/\delta d$, since

$$\delta d = (d^2 \cos i/bR)\delta(\Delta N) \tag{4}$$

is inversely proportional to the square of the long distance d and the area of the ray parallelogram $2bR$. Thus with the above constants, if d is 2 kilometers, $\delta(\Delta N) = 10^{-4}$ cm., then

$$\delta d = (2 \times 10^{5})^2 \times 0.71 \times 10^{-4}/200 \times 10 = 14 \times 10^{2} \text{ cm.} = 14 \text{ meters.}$$

Thus an object at about a mile should be located to about 30 feet. Per fringes of mean wave length λ, moreover, $\delta d = \lambda d^2/2bR$, the placement should be about 6 meters at 2 kilometers. I have stated the case, of course, merely for the interferometer, not for subsidiary optical appurtenances.

NATIONAL RESEARCH COUNCIL

MEETINGS OF THE EXECUTIVE COUNCIL

The tenth meeting of the Executive Committee was held at the offices of the Council on January 25, 1917. Messrs Carty, Chittenden, Conklin, Dunn, Pupin, Vaughan, Welch, and the Secretary were present.

The Secretary presented Dr. Holmes' report, dated January 16th, on the composition of the Committee on Anthropology. It was understood that this committee will be formed in coöperation with the American Association for the Advancement of Science, as has been done with other science committees.

The Secretary presented the following resolution of the National Advisory Committee for Aeronautics, accepting designation by the National Research Council as the Aeronautical Committee of the Research Council:

RESOLVED: That the invitation of the National Research Council that the members of the National Advisory Committee for Aeronautics act as the Committee on Aeronautics of the National Research Council be accepted on appointment of its members by the National Research Council as such committee.

The Executive Committee adopted the following resolutions:

RESOLVED: That the National Research Council acknowledges the acceptance by the National Advisory Committee for Aeronautics of the invitation of the National Research Council to serve as its "Aeronautics Committee" and hereby appoints Dr. Charles D. Walcott, Chairman, and Dr. Joseph S. Ames, Prof. Chas. F. Marvin, Prof. M. I. Pupin, Brig. Gen. Geo. O. Squier, and Dr. S. W. Stratton, members of the Aeronautics Committee of the National Research Council.

RESOLVED: That the Executive Committee of the National Research Council cordially thanks the National Advisory Committee for Aeronautics for its generous action in placing its services at the disposal of the National Research Council in this matter.

Dr. Vaughan then presented the matter of the Medicine and the Hygiene Committees, urging that these two committees be merged. After considerable discussion, it was agreed that the former action of the Executive Committee creating separate committees for medicine and for hygiene be reconsidered, and that one committee, to be designated the Medicine and Hygiene Committee, be appointed. Dr. Vaughan then presented a list of names for this committee; explaining the need of a large committee by the fact that the many different aspects of medicine and hygiene must be considered.

The Executive Committee approved the appointment of the persons listed and authorized the organization of the committee.

The eleventh meeting of the Executive Committee was held on February 7, 1917. Messrs. Carty, Dunn, Pupin, and the Secretary were present; also Dr. Bogert by invitation.

The meeting was devoted principally to the discussion of the appointment of a committee of submarine detection, recommended in a telegram received from

the Chairman of the Council. It was voted to call a joint meeting of the Executive Committee and the Military Committee in Washington on February 17 to act upon this question.

The general policy of the Research Council in regard to the giving out of information was discussed; and it was voted that the chairmen of all committees be requested not to give out any statements, written or oral, regarding matters of public policy or interest, save through the intermediary of the office of the Council.

Dr. Bogert gave an informal account of some of the work of the Chemistry Committee. He recommended the appointment of older, retired chemists as advisory members of the committee. He also reported the appointment of Wilder D. Bancroft, of Cornell University, as Chairman of the Sub-Committee on Electro-chemistry. All of Dr. Bogert's recommendations were agreed to by the Committee.

The twelfth meeting of the Executive Committee, consisting in a joint session with the Military Committee of the National Research Council, was held on February 17, 1917, at the Smithsonian Institution, Washington. Messrs. Carty, Chittenden, Conklin, Dunn, Millikan, Pearl, Pupin, Stratton, Vaughan, Walcott, and Welch, and the Secretary of the Executive Committee, and General Gorgas, General Squier, Admiral Taylor, and Admiral Griffin of the Military Committee, were present; also, by invitation, Dr. Bogert, Chairman of the Chemistry Committee.

Dr. Stratton, speaking as Secretary of the Military Committee, told of two important problems that are already under way, which had originated with this committee. The first is the disposition of the opium confiscated by the Government; the second, the preparation of a specification for a good blanket. The Military Committee was of the opinion that the Government should use confiscated opium, turning it into harmless salt rather than to destroy it. Action to this end has been taken. Conferences regarding the matter of bla ket specifications are under way.

The procedure to be followed by the Military Committee was discussed; and the Executive Committee agreed that the Military Committee shall correspond with the chairmen of the various other committees of the Council which may be concerned in the problems originating with the Military Committee.

It was voted to recommend to the President of the National Academy of Sciences that Admiral Ralph Earle, Chief of the Bureau of Ordnance of the Navy Department, and Mr. Herbert C. Hoover be made members of the Research Council. The former thereby becomes a member of the Military Committee.

The Secretary reported that Eliakim H. Moore had been made a member of the Council and Chairman of the Mathematics Committee.

It was voted that an Engineering Committee be authorized and that the

personnel be determined by conference between members of the Executive Committee and the presidents of the national engineering societies, in order that the full coöperation of the engineers of the country might be secured.

It was voted that a Committee on Anatomy be authorized and that Dr. Hale be requested to nominate its chairman.

At this point the meeting adjourned, and the members assembled at a luncheon kindly provided by Dr. and Mrs. Walcott. Members of the Council of National Defense and its Advisory Commission, namely, Messrs. Godfrey, Coffin, and Gifford, joined the members of the Council at luncheon.

The members reassembled thereafter in conference with the members of the Council of National Defense; and, after an explanation by Dr. Carty of the formation and scope of the work of the National Research Council, the relations of the two bodies were discussed.

The thirteenth meeting of the Executive Committee was held on February 26, 1917. Messrs. Carty, Dunn, Pupin, and the Secretary were present.

The particular object of the meeting was to consider a resolution to be forwarded to the Council of National Defense, defining the form of relations that the National Research Council desires to hold with the Council of National Defense. After full discussion, the following resolution was adopted:

RESOLVED: That the National Research Council, established at the request of the President of the United States for the organization and promotion of scientific research in the interest of national defense and national welfare, is of the opinion that its services to the National Government in its coöperation with the Council of National Defense will be most effective if acting directly with the Council of National Defense through its Director.

The Secretary was instructed to transmit this to the Director of the Council of National Defense as an expression of the attitude of the Research Council.

The fourteenth meeting of the Executive Committee of the National Research Council was held on March 7, 1917. Messrs. Carty, Chittenden, Conklin, Dunn, Stratton, and the Secretary were present.

The Secretary announced the completion of the Committees on Astronomy, Agriculture, Physiology, Geology; and stated that the Committees on Botany, Zoology, and Anthropology have not yet been completed. He reported Dr. Hale's recommendation that a Committee on Anatomy be authorized.

Messrs. John C. Merriam and Charles R. Cross were appointed members of the Census Committee.

The Secretary reported that Carl L. Alsberg and Alonzo E. Taylor have been appointed members of the National Research Council by the President of the National Academy of Sciences.

The Secretary read the offer of the faculty of Sloane Laboratory of Yale University of its services and facilities, to the National Research Council for research work for national defense. Dr. Stratton presented letters with similar offers from the American Society of Mechanical Engineers, the General

Electric Company, and the Jefferson Physical Laboratory of Harvard University. These offers all placed at the disposal of the Research Council valuable facilities for conducting research. The Executive Committee instructed the Secretary to prepare and transmit a resolution, expressing appreciation of these offers; and to inform the Council of National Defense that the National Research Council holds these facilities at its disposal.

The Secretary presented Dr. W. M. Davis's report on the work of the Geography Committee. It was received, and the Secretary was instructed to inform Dr. Davis that the Executive Committee approves the proposed plan.

The Secretary presented the report of Dr. J. M. Clarke, Chairman of the Geology Committee, requesting the Executive Committee to approve his action in taking steps to better the instruction in geology in the engineering schools and colleges of the country. The Executive Committee voted to endorse Dr. Clarke's action. Reports were also presented from Prof. E. C. Pickering, Chairman of the Committee on Astronomy, and Dr. V. C. Vaughan, Chairman of the Committee on Medicine. It was voted that an Engineering Committee be authorized, to consist of the following members of the National Research Council, with whom others may be joined from time to time by the Executive Committee: Gano Dunn (Chairman), J. A. Brashear, J. J. Carty, W. F. M. Goss, Clemens Herschel, C. F. Rand, C. E. Skinner, S. W. Stratton, Ambrose Swasey, and Elihu Thomson.

It was voted to appoint a new Nitrate Supply Committee to consist of the Chiefs of the Departments of Ordnance of the Army and of the Navy, repreentatives of the Department of Agriculture, the Bureau of Mines, and Bureau of Standards, and Messrs. Leo H. Baekeland, Gano Dunn, C. H. Herty, A. A. Noyes, and W. R. Whitney, members of the former Nitrate Supply Committee. (This committee was subsequently replaced by a similarly constituted one appointed officially by the Secretary of War.)

The Secretary reported that in response to the resolution adopted by the National Research Council, a resolution was adopted by the Council of National Defense on the 28th of February as follows:

> RESOLVED: That the Council of National Defense, recognizing that the National Research Council, at the request of the President of the United States, has organized the scientific forces of the country in the interest of national defense and national welfare, requests that the National Research Council coöperate with it in matters pertaining to scientific research for national defense, and, to this end, the Council of National Defense suggests that the National Research Council appoint a committee of not more than three, at least one of whom shall be located in Washington, for the purpose of maintaining active relations with the Director of the Council of National Defense.

The Secretary reported the appointment of a Sub-Committee on Smokeless Powder by the Military Committee. This Sub-Committee is composed of Admiral Griffin, Admiral Earle, Messrs. C. D. Walcott, Comey, and Harry T. Brown.

The fifteenth meeting was held in New York on March 22, 1917. Messrs. Carty, Conklin, Dunn, Hale, and the Secretary were present; also upon invitation Drs. M. T. Bogert and J. M. Clarke.

It was voted to ask Dr. Charles H. Herty to become a member of the Publicity Committee and to take especial charge of chemical publicity in accordance with the general publicity policy of the Publicity Committee of the Council.

Dr. Hale spoke of the urgent need of acting in accordance with the resolution of the Council of National Defense, by appointing a committee of three to work with the Council of National Defense in Washington, of which one member, as requested by the Council of National Defense, shall be in Washington permanently, with headquarters in close connection with the Council of National Defense. After full discussion of the matter it was voted that a committee of three be appointed to coöperate with the Council of National Defense, in accordance with the resolution of that Council, to consist of Dr. C. D. Walcott, Dr. S. W. Stratton, and Dr. R. A. Millikan; that an office be secured in Washington in the Munsey Building as headquarters of the Research Council, and that Dr. Millikan be asked to take charge of it.

Dr. Hale stated that Mr. Tod Ford of Los Angeles is willing to come to Washington and give all his time to the work of the Research Council. It was voted that Mr. Ford be employed as Assistant Secretary in the office of the Research Council in Washington.

Dr. Hale proposed the formation of a volunteer corps of scientific observers to go to Europe to study the development of scientific research in the problems of the war. After discussion it was voted that Dr. Hale be authorized to appoint such persons as he elects to proceed to Europe to study the conditions there brought about by the war, and to take such other steps as he deems advisable to further this general purpose.

Dr. Clarke, Chairman of the Geology Committee, then reported briefly upon the work of his committee. He asked the approval of two sub-committees, one on Camp Sites, another on the Location of Distant Artillery by Seismological Measurements. He was authorized to appoint them, with Dr. Penrose as Chairman of the Sub-committee on Camp Sites, and Dr. Woodworth of that of Seismological Measurements.

Dr. Hale then offered his resignation as Chairman of the Committee on Research in Educational Institutions, and suggested that Dr. R. H. Chittenden be asked to accept the Chairmanship in his stead. The committee accepted with regret Dr. Hale's resignation and approved the appointment of Dr. Chittenden.

In view of the proffered assistance of the American Institute of Consulting Engineers, it was voted that the President of the American Institute of Consulting Engineers be asked to suggest one of its members to be appointed a member of the National Research Council.

CARY T. HUTCHINSON, *Secretary.*

NATIONAL RESEARCH COUNCIL

JOINT MEETING OF THE EXECUTIVE, MILITARY, AND ENGINEERING COMMITTEES

This meeting was held in Washington, on May 3, 1917, at 10 a.m.

There were present: Messrs. John A. Brashear, John J. Carty, Russell H. Chittenden, Gano Dunn, William F. Durand, John R. Freeman, Hollis Godfrey, William C. Gorgas, Robert S. Griffin, George E. Hale, Frank B. Jewett, Van H. Manning, Edgar Marburg, Charles F. Marvin, C. E. Mendenhall, Robert A. Millikan, F. H. Newell, Arthur A. Noyes, Michael I. Pupin, Albert Sauveur, Clayton H. Sharp, C. E. Skinner, George O. Smith, George O. Squier, Lewis B. Stillwell, S. W. Stratton, Ambrose Swasey, David W. Taylor, Chas. D. Young, Charles D. Walcott, and Pope Yeatman. Dr. C. D. Walcott presided.

The meeting was devoted to an extended discussion of the functions to be fulfilled and the work to be undertaken by the Engineering Committee.

FIRST MEETING OF THE ENGINEERING COMMITTEE

This meeting was held in Washington, on May 3, 1917, at 2.10 p.m.

Present: Messrs. Gano Dunn (Chairman), John A. Brashear, John J. Carty, William F. Durand, John R. Freeman, Hollis Godfrey, Frank B. Jewett, Edgar Marburg, F. H. Newell, Michael I. Pupon, Albert Sauveur, Clayton H. Sharp, C. E. Skinner, Lewis B. Stillwell, George F. Swain, Ambrose Swasey, Pope Yeatman, and Charles D. Young, members of the Committee; also G. E. Hale, A. A. Noyes, and R. E. Millikan of the Council.

The chairman introduced the question of the organization of the Engineering Committee. Mr. J. R. Freeman moved that one man be appointed to act as director of the work of the Engineering Committee, who should live in Washington. This motion was carried.

Mr. Swain moved that W. F. Durand be the Washington head of the Engineering Committee, to be known as Vice-Chairman of the Committee, with Gano Dunn remaining as Chairman. This motion was carried, and Mr. Durand accepted the appointment.

It was voted that the Secretary of the National Research Council be appointed Secretary of the Engineering Committee.

The matter of rules and procedure of the Engineering Committee was then brought up, and it was voted that a Committee on Procedure be appointed, with power to adopt rules. The Chairman appointed Messrs. Durand, Young, and Stillwell to be such a committee.

A discussion of various phases of the work of the Committee, participated in by many of the members present, took place.

CARY T. HUTCHINSON, *Secretary.*

NATIONAL RESEARCH COUNCIL

REPORT OF THE ASTRONOMY COMMITTEE

The present report relates only to the scientific needs of Astronomy. Its applications to the possible services that astonomers can render in the war, as a part of the work done by the National Research Council in connection with the Council of National Defense, will be made the subject of a separate study.

The report of the Committee on Astronomy of the Committee of One Hundred (*Science*, **45**, 135) gives the views of a majority of the members of the present Astronomy Committee. It shows the uses that could be made at once of a fund for astronomical research. They need not all be repeated here, but two are of such importance and general application that attention may be called to them.

First, aiding existing southern observatories, or establishing new observing stations to render our knowledge of the southern stars comparable with that of the northern stars. As the resources of northern observatories are far greater than of those south of the Equator, much might be accomplished by taking photographs of the southern stars, and sending them north for measurement, reduction, and perhaps discussion.

Secondly, securing the aid of very large reflectors, both north and south, for the extension of nearly every research to very faint stars. This is especially the case in clusters, or other objects, where photographs with short exposures would furnish material for prolonged study. Experts all over the world might thus be provided with material of the greatest value, while the owners of the telescopes would have the satisfaction of having their photographs discussed by those best qualified to do so. The continuation of the investigation with large reflectors of the radiation of stars and planets is regarded by many as of paramount importance.

Letters are published in *Science*, **41**, 82, giving the needs of twelve leading American astronomers. In almost every case, the demand was for more assistants to aid in extensive routine observations. A relatively very large increase of output could thus be secured. Six of these astronomers are members of the present Committee.

The publication each year of a brief statement of the work done by every American observatory engaged in research, as is now done by European observatories, would aid greatly in forming plans for coöperation.

Examples are given below of large routine investigations needed at the present time. Several of them, such as 2, 4, 8, 17, and 20, are already making excellent progress, according to a definite system. In many cases, plans could best be carried out by small committees of experts. The American Astronomical Society, which, with few exceptions, includes among its members all the leading astronomers of the country, has already appointed several such committees.

For statistical purposes, it is very desirable to include all stars brighter than a given magnitude. This limit is often that for which the desired observations can be obtained. If not, stars of special interest should be included, and in some cases a fixed number of stars of each fainter magnitude. Preference should here be given to the standard regions adopted at Groningen and Harvard.

1. The absolute positions of the stars from observations of the Sun, Mercury, and Venus. These objects are difficult to observe visually, and a trial of photographic methods, either by direct measurement, or by a photographic transit circle, is suggested.

2. Positions of all stars of the ninth magnitude, and brighter, with photographic doublets.

3. Precise positions of standard stars, generally of about the ninth magnitude, needed for the reduction of No. 2. Each star should be observed with transit micrometers, attached to first class meridian circles, on at least three nights at two observatories, if feasible. The aid of national observatories should be secured in this work, since they are best qualified to undertake it. These stars should be selected whenever possible from the list of intermediary stars of the Comité International Permanent. Nos. 2 and 3 should be carried on simultaneously.

4. Proper motions of all stars of the magnitude 7.5, or brighter.

5. Proper motions of stars in spiral, and other, nebulae.

6. Restoration of the stations for determining variations in latitude both visually and photographically.

7. Sufficient measures of all known double stars to determine the relative positions of the components, and if they have perceptible motions to furnish adequate material for an orbit. In the first case, these observations should be made with three telescopes, with a computed probable error not exceeding $\pm 0''.05$. These observations should be repeated every ten years, or, in the case of known b'naries of short period, more frequently. For many stars, the material needed already exists.

8. Parallaxes of all stars of the sixth magnitude, and brighter, and of a selected list including variables, stars having large proper motion or parallax, binaries, nebulae, etc. The same stars should be observed with several telescopes to eliminate systematic errors, as far as possible. Some clusters, and stars of Class B, whose parallaxes are presumably small, should therefore be included.

9. Precise positions by modern methods, photography and transit micrometer, of the Moon and major planets.

10. Orbits and ephemerides of asteroids and comets so far as this is not provided for by the Rechen-Institut. The loss of a faint asteroid may sometimes be avoided by promptly computing a circular orbit for it.

11. Spectra of special stars too faint to be classified on existing photographs. They can probably be obtained by a focal plane spectroscope, or objective prism, attached to a large reflector.

12. Peculiarities of spectra, including the relative intensities of lines, especially of those of wave lengths 4216, 4455, etc. Study of lines of great and small wave-lengths. Intensity of light of different wave-lengths.

13. Radial velocities of stars, including all of magnitude 6.0, and brighter, with a computed probable error not exceeding 3 km. Radial velocities of a selected list of stars like those in No. 8.

14. Radial velocities of spectroscopic binaries. Minimum number of good determinations forty, with at least one in each twenty-fourth of the period.

15. Photographic and photovisual magnitudes of a Durchmusterung of all stars of the ninth magnitude, and brighter, on the international scale. It may be best to begin with 40,000 stars, one in each square degree of about the ninth magnitude, or with the standard stars of No. 3.

16. Photographic and photovisual magnitudes of selected lists of faint stars.

17. Photometric, photographic, or visual determinations of the brightness of all variables of long period, or irregular, having a range of four magnitudes, or more, or three magnitudes when of the ninth magnitude, or brighter, at maximum.

18. Light curve of all variables of short period. For the bright stars the photoelectric cell should be used. Dividing the period into twenty-four equal parts, a point on the curve should be determined in each of these parts with a probable error not exceeding ± 0.02 magn. Observations should be made every five years, at phases when the light is changing most rapidly, to determine the variations in the period. In the case of globular clusters and the Magellanic Clouds, photographs with large reflectors are much to be desired to extend the work to the fainter stars.

19. Measures like those of No. 18 of all Algol variables. In addition, at least twenty points should be determined at nearly equal intervals during the primary, and secondary minimum, if any exists.

20. A catalogue of all stars of the magnitude 6.5, and brighter, giving for each the approximate position, proper motion, radial velocity, parallax, magnitude, spectrum, color index, etc. The type to be kept standing and a new edition issued every three years, giving corrected values computed by experts who should maintain a bibliography accessible to all investigators.

EDWARD C. PICKERING, *Chairman*,

W. W. CAMPBELL,	GEORGE E. HALE,
GEORGE C. COMSTOCK,	HENRY N. RUSSELL,
W. S. EICHELBERGER,	FRANK SCHLESINGER,
EDWIN B. FROST,	JOEL STEBBINS.